october 1959
the
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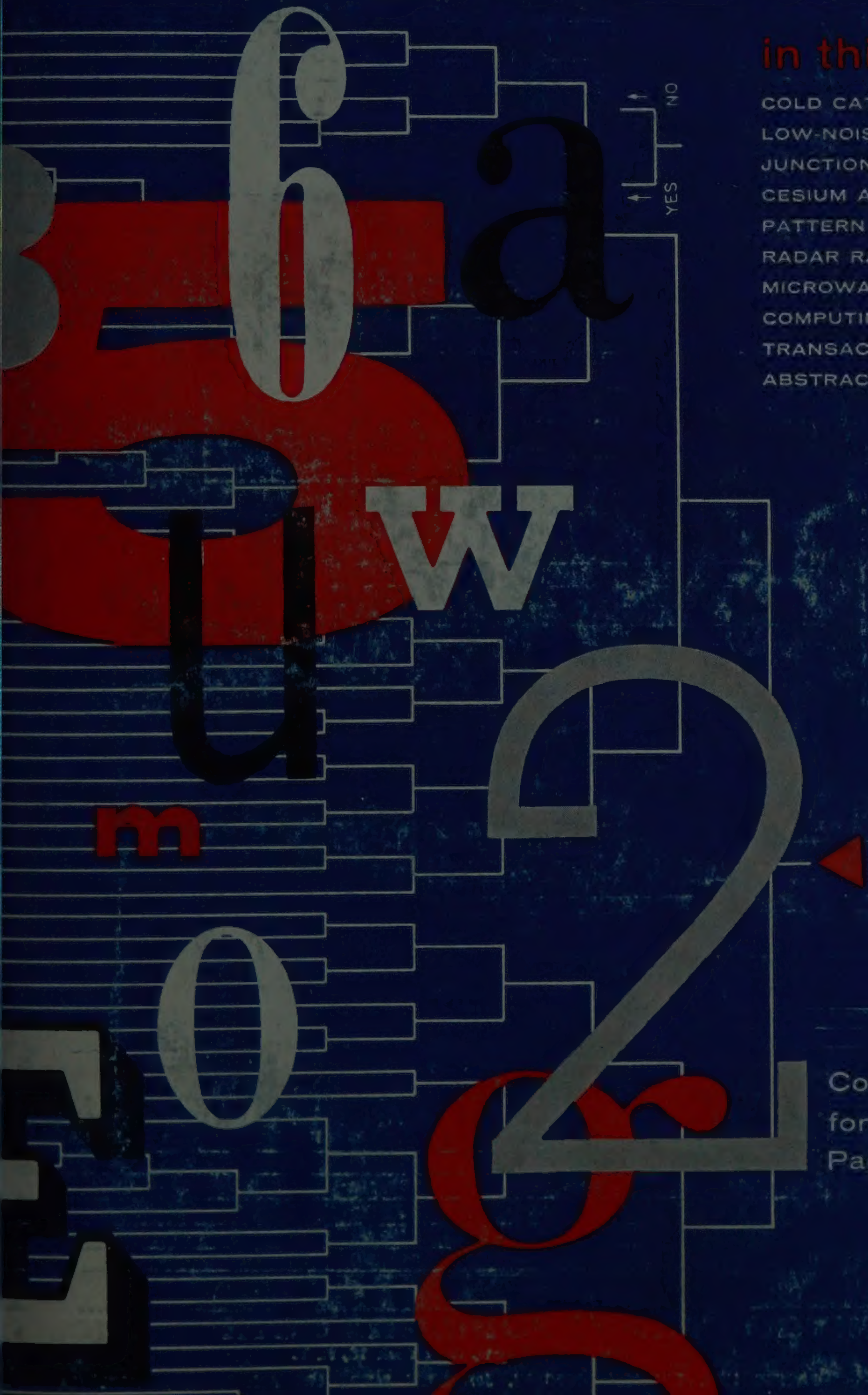
of
radio
engineers

roceedings of the IRE



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Computer Program
for Character Recognition:
Page 1737

VOLUME 47, NUMBER 10

October, 1959

published monthly by The Institute of Radio Engineers, Inc.

Proceedings of the IRE®

contents

COVER

A computer program has been developed at Bell Telephone Laboratories for identifying alphanumeric characters by systematically testing their shapes for certain distinguishing features. The sequence of tests is illustrated by the flow chart on the cover (from right to left), and is described further on page 1737.

published monthly by The Institute of Radio Engineers, Inc.

Proceedings of the IRE®

continued

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Thirty days advance notice is required for change of address. Price per copy: members of the Institute of Radio Engineers, one additional copy $1.25; non-members $2.25. Yearly subscription price: to members $9.00, one additional subscription $13.50; to non-members in United States, Canada, and U. S. Possessions $18.00; to non-members in foreign countries $19.00. Second-class postage paid at Menasha, Wisconsin under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927. Printed in U.S.A.

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in these two dependable wirewound resistors

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VITREOUS-ENAMEL POWER RESISTORS

Sprague's new improved construction gives even greater reliability and higher wattage ratings to famous Blue Jacket miniature axial lead resistors.

A look at the small *actual sizes* illustrated, emphasizes how ideal they are for use in miniature electronic equipment with either conventional wiring or printed wiring boards.

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TAB-TYPE BLUE JACKETS: For industrial applications, a wide selection of wattage ratings from 5 to 218 watts are available in Sprague's famous Tab-Type Blue Jacket close-tolerance, power-type wirewound resistors. Ideal for use in radio transmitters, electronic and industrial equipment, etc. **For complete data, send for Engineering Bulletin 7400A.**

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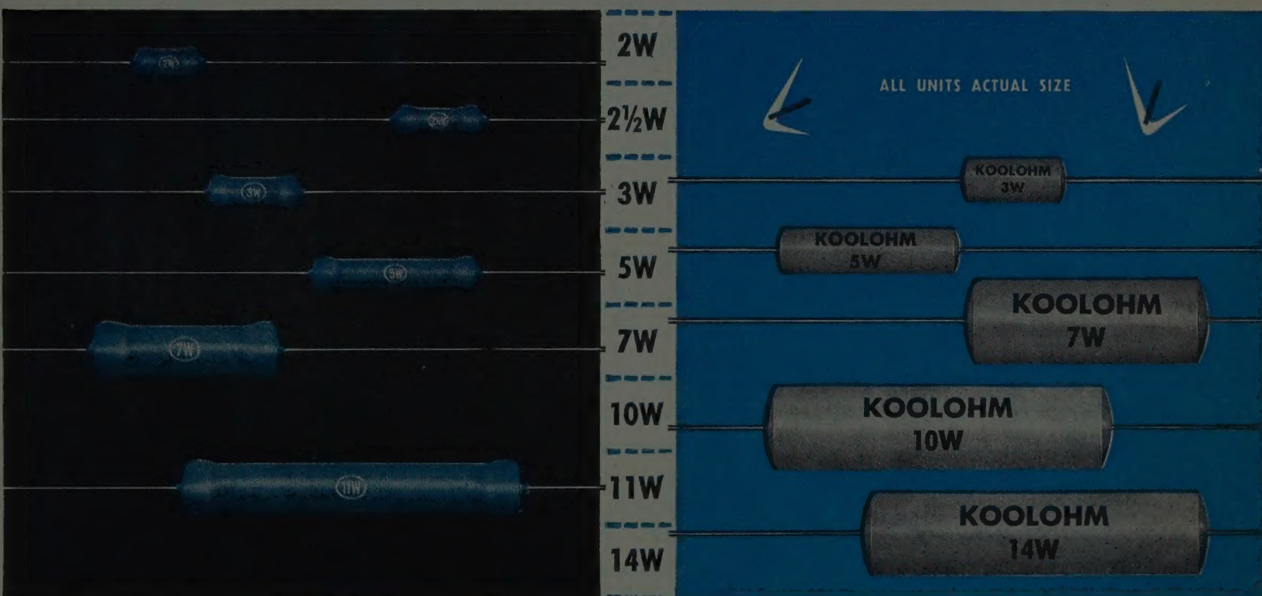
New Koolohm construction features include welded leads and winding terminations—Ceron ceramic-insulated resistance wire, wound on special ceramic core—multi-layer non-inductive windings or high resistance value conventional windings—sealed, insulated, non-porous ceramic outer shells—*aged-on-load* to stabilize resistance value.

You can depend upon them to carry maximum rated load for any given physical size.

Send for Engineering Bulletin 7300 for complete technical data.



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SPRAGUE COMPONENTS: RESISTORS • CAPACITORS • MAGNETIC COMPONENTS • TRANSISTORS • INTERFERENCE FILTERS • PULSE NETWORKS • HIGH TEMPERATURE MAGNET WIRE • PRINTED CIRCUITS

The two transistorized binary counters described in this "advertisement," are examples of a development from our Department of Reconnaissance Systems. It is expected that these counters will soon enable you to count the cycles of the local oscillator of your TV receiver. The counters, although extremely fast, are simple and dependable. If you need more information on high speed transistorized counters, Al Basil or Al Boecker will be glad to give you additional details on these and similar counters.

HIGH-SPEED TRANSISTOR BINARY COUNTERS

The increasing demands for improved performance and greater reliability have led to the development of some simple high-speed binary counters. These binaries are not critical in regard to supply voltage, temperature, or drive. A novel technique that utilizes inductances for steering, provides dependable switching.

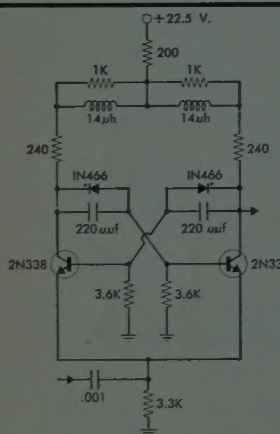

FIGURE 1
BASIC HIGH-SPEED BINARY

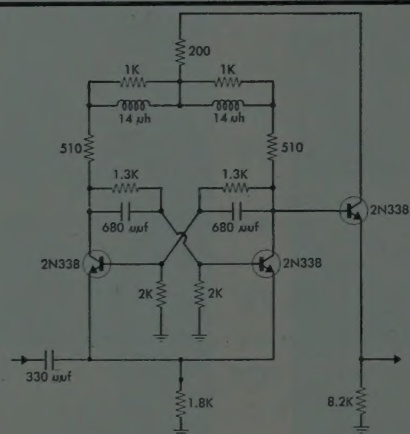

FIGURE 2
MODIFIED HIGH-SPEED BINARY

Transistor characteristics that influence the speed of operation are alpha cutoff frequency, collector capacitance, parasitic mounting capacitances, delay time and carrier storage effects. Alpha cutoff and collector capacitance are determined by the transistor design. The parasitic mounting capacitances are caused by the required leads, supports and housing for the transistor. The delay time and carrier storage effects are a function of transistor design and method of operation. Parasitic capacitances can be reduced by careful layout and choice of components. Carrier storage effects can be minimized by not operating the transistor into the region of saturation which allows a much higher speed of operation.

Diode clamps are one method of avoiding saturation. Diode recovery times impose upper speed limits on clamped binaries not otherwise restricted.

A reduction of the necessary collector voltage swing will increase the speed of operation since stray capacitances will require less of a charge for the transition. The use of zener diodes for cross-coupling minimizes the required collector voltage swing.

Reliable steering is a necessity for any practical counter. Many high-speed binaries have used two or more additional transistors, diodes, delay lines or combinations for steering. The use of inductive steering eliminates the need for these components and ensures proper switching.

A requirement for a 10-Mc binary counter utilizing available silicon transistors was met by the basic binary shown in figure 1. This binary differs from the conventional binary in that it is a non-saturating current-switching binary that uses zener diode cross-coupling and a pair of inductances for steering. It has operated with a ±6 volt variation in the nominal 22.5 volt supply. The amplitude, width, and rate of triggering pulses applied to the emitters are not critical.

A suitable positive pulse on the emitters cuts off the conducting transistor and prevents the non-conducting transistor from turning on during the trigger. A transient will be set up by the inductance in the collector circuit of the transistor that was conducting. This inductance will resist the current change in a damped manner causing the base of the previously non-conducting transistor to be more positive than the opposite base. At the termination of the trigger pulse, the binary is set to the opposite state.

Inductive steering is not critical. This has been shown by an experimental well-balanced binary that has operated with sine wave trigger from 1 to 11 megacycles. Another experimental binary with 2N695 germanium transistors and modified values of the components has operated up to 70 megacycles and has shown the same non-critical features of the basic high-speed binary.

A modified high-speed binary for lower operating rates is shown in figure 2. This permits the replacement of the zener diodes by resistors and capacitors. The collector voltage swing is increased which allows the following binary to be triggered by an isolating emitter follower driver. The modified high-speed binary has been used for rates below 1.5 megacycles.

A complete bound set of our third series of articles is available on request. Write to Harold Hechtman at AIL for your set.

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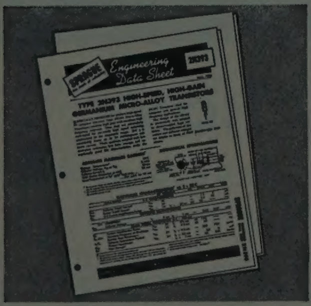
*micro-alloy transistors from SPRAGUE**

2N393

HIGH-SPEED, HIGH-GAIN MICRO-ALLOY TRANSISTORS for modern digital computer circuitry

TYPE 2N393 Micro-Alloy Transistors combine high gain with excellent high frequency response to meet the demands of high-speed computer switching applications in the megacycle range. Low saturation resistance, low hole storage, and exceptionally good life characteristics make these transistors top performers in computer circuits as well as in general high-frequency applications.

D-C β is remarkably linear up to 50 milliamperes collector current. The design of the 2N393 is particularly well adapted to direct-coupled logic circuitry. The polarities of the emitter and collector voltages are similar to those of PNP junction-type transistors.



Made by electrochemical manufacturing techniques, Sprague Micro-Alloy Transistors are uniformly reliable and very reasonably priced.

Write for complete engineering data sheets to Sprague Electric Company, 235 Marshall Street, North Adams, Massachusetts.

2N393

	Min.	Typ.
h_{FE}	20	95
f_{max}	40	60

ACTUAL SIZE

* *Sprague Type 2N393 micro-alloy transistors are fully licensed under Philco patents. All Sprague and Philco transistors having the same type numbers are manufactured to the same specifications and are fully interchangeable. You have two sources of supply when you use Sprague transistors!*

SPRAGUE COMPONENTS:
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NEW EXPERIMENT IN TELEPHONY

It could speed up "dialing." Bell Laboratories people created it—and now it's being tested.

The telephone you see above embodies an important new concept. It "dials" by means of push buttons—promises more convenient telephoning. Bell System engineers are currently testing it for public reaction. Bell Telephone Laboratories developed it.

The Laboratories' invention of the transistor makes it possible. For the transistor permits a new kind of calling signal generator, mounted within the instrument.

To insure ease of operation, psychologists studied human reactions to various finger pressures and sizes and arrangements of buttons. All factors affecting speed and accuracy were thoroughly evaluated. Electrical and mechanical engineers brought together the human and physical factors, created a practical piece of apparatus. Industrial designers worked out the functional shape.

The new instrument sends a calling signal quite different from that of your present telephone. This poses a problem. Complex automatic switching must be changed to handle the new signals as well as the old ones. Switching engineers must devise ways to make this change in *thousands* of central offices—economically.

Most of the challenges have been met. Final judgment on this new concept depends on the outcome of field tests. Meanwhile, Bell Laboratories continues in its task of originating and developing devices to improve your Bell System telephone service.

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Electronic signals that report the truth, the whole truth, and nothing but . . . wring the best performance from missile systems. By pushing beyond known capabilities in sensitivity and accuracy, Texas Instruments is producing "high IQ" systems and equipments for a dozen guided vehicles used in every basic mission: air-to-air, air-to-surface, surface-to-air, surface-to-surface — IRBM and ICBM—plus drone sensors and satellite instrumentation. TI exceeds tough specs against tight deadlines, regularly . . . specs asking solutions to problems never posed before. For detailed discussion, cleared personnel please write or call: SERVICE ENGINEERING DEPARTMENT.

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Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.

Δ

October 12-14, 1959

National Electronics Conference, Hotel Sherman, Chicago, Ill.

Exhibits: Mr. Robert E. Bard, General Radio Co., 6605 W. North Ave., Oak Park, Ill.

October 26-28, 1959

East Coast Aeronautical & Navigational Electronics Conference, Lord Baltimore Hotel & 7th Regiment Armory, Baltimore, Md.

Exhibits: Mr. R. L. Pigeon, Westinghouse Electric Corp., Air Arm Div., P.O. Box 746, Baltimore, Md.

November 3-5, 1959

MAECON, Mid-America Electronics Convention, Municipal Auditorium, Kansas City, Mo.

Exhibits: Mr. John V. Parks, Bendix Aviation Corp., P.O. Box 1159, Kansas City 41, Mo.

November 9-11, 1959

Fourth Instrumentation Conference, Atlanta, Ga.

Exhibits: Dr. B. J. Dasher, School of E.E., Georgia Institute of Technology, Atlanta 13, Ga.

November 10-12, 1959

Twelfth Annual Electrical Techniques in Medicine and Biology Conference, Sheraton Hotel, Philadelphia, Pa.

Exhibits: Mr. Lewis Winner, 152 West 42nd St., New York 36, N.Y.

November 16-19, 1959

Conference on Magnetism & Magnetic Materials, Sheraton-Cadillac Hotel, Detroit, Mich.

Exhibits: Mr. G. G. Scott, General Motors Co., Research Lab., Warren, Mich.

November 17-19, 1959

Northeast Electronics Research and Engineering Meeting (NEREM), Boston Commonwealth Armory, Boston, Mass.

Exhibits: Miss Shirley Whitcher, IRE Boston Office, 73 Tremont Street, Boston, Mass.

December 1-3, 1959

Eastern Joint Computer Conference, Hotel Statler, Boston, Mass.

Exhibits: John Leslie Whitlock Associates, 6044 Ninth St. North, Arlington 5, Va.

December 3-4, 1959

PGVC Annual Meeting, Colonial Inn & Desert Ranch, St. Petersburg, Fla.

Exhibits: Mr. A. W. Sullivan, Minneapolis-Honeywell Regulator Co., 13350 U. S. 19, St. Petersburg, Fla.

(Continued on page 10A)

KAY ELECTRIC . . . first in Noise Figure Measurement

ALL NEW!

KAY *Therma-Node*

CAT. No. 770

NEW NOISE GENERATION TECHNIQUE COVERS 0.5 TO 1100 MC — ACCURATE TO ± 0.1 DB

No Gas Discharge Tubes, Diodes, or External Cables

The new Kay *Therma-Node* is shown here operating in conjunction with a Kay *DRD* (Direct Reading Digital) *Attenuator* (Model 40-0)

The new Kay *Therma-Node* is a highly accurate commercial noise generator based on the measurement of the noise temperature of a heated resistive element. It covers an extremely wide frequency range of 0.5 to 1100 mc, either fixed or tuned, is accurate to ±0.1 db, and provides noise temperatures ranging from 2000° K to 2400° K readable to ±2%—sufficient to accommodate noise figure measurements up to 10 db. Lower noise temperatures (down to room temperatures) and various impedances are attainable with suitable matching networks and attenuators. No gas discharge tubes, diodes, or external cables are required. The resistive element that generates the noise has a life expectancy of more than 10,000 hours of continuous or intermittent use; the few active devices used in the *Therma-Node* are of solid state, reducing maintenance to a minimum. The unit can be operated on 117V., 60 cps or 24 volt battery.

Write for Kay Catalog 1959-A

SPECIFICATIONS

FIXED TUNING RANGE: 1-500 mc.
Output Impedance: 50 ohms.
Maximum VSWR: 1.2 VSWR from 4 mc to 200 mc; 1.4 VSWR from 2 mc to 400 mc; 2.0 VSWR from 1 mc to 500 mc.
Noise Temperature: 2000°-2400° K, measured within 2%.

VARIABLE TUNING RANGE: 5-1050 mc.
Output Impedance: 50 ohms.
Maximum VSWR: 1.1 at center frequency.
Minimum Bandwith for Average VSWR of 1.4: From 200 to 1050 mc—200 mc; below 200 mc the unit is broadband down to 1 mc.
Noise Temperature: 2000°-2400° K, measured within 2%.

Dimensions: 10½" x 7" x 4".
Weight: 8 lbs.
Price: $495.00, f.o.b. factory.

OTHER KAY NOISE GENERATORS

Instrument & Cat. No.	Frequency Range (mc)	Noise Figure Range (db)	Output Impedance (ohms)	Price f.o.b. factory
Mega-Node 240-B	5-220	0-16 at 50 ohms 0-23.8 at 300 ohms	unbal.—50, 75, 150, 300, ∞ bal.—100, 150, 300, 600, ∞	$345.00
Mega-Node 175-A	50-500	0-19	balanced—300	$345.00
Mega-Node 403-A	3-500	0-19	unbalanced—50	$345.00
Mega-Node-Sr. 250-B	10-3000	0-20	unbalanced—50	$790.00
Rada-Node 600-A	5-400	0-23.8 depending on impedance	unbalanced as specified	$1495.00
	10-3000	0-20	unbal. nom. 50	$1965.00
	1120-26,500	15.28 or 15.8	waveguide	†
Micro-Node 1080-A	3700-4200	0-15.8	waveguide	$795.00
*Microwave Mega-Nodes**	1120-26,500	15.28 or 15.8	waveguide	$175.00 to $595.00

† Price varies with **Microwave Mega-Node** discharge tube used as accessory.
* Ideally suited for noise figure measurement in radar communication.

KAY ELECTRIC COMPANY

Dept. I-10 Maple Avenue, Pine Brook, N.J. CApital 6-4000

Meetings with Exhibits

(Continued from page 8A)

February 3-5, 1960
PGMIL Winter Meeting, Ambassador Hotel, Los Angeles, Calif.
Exhibits: Mr. Einer Ingebretson, Summers Gyroscope Co., Santa Monica, Calif.

March 21-24, 1960
Radio Engineering Show and IRE National Convention, Waldorf-Astoria Hotel and New York Coliseum, New York, N.Y.
Exhibits: Mr. William C. Copp, Institute of Radio Engineers, 72 West 45th St., New York 36, N.Y.

April 20-22, 1960
SWIRECO, Southwestern IRE Regional Conference & Electronics Show, Shamrock-Hilton Hotel, Houston, Texas.
Exhibits: Mr. A. D. Seixas, SWIRECO, P.O. Box 22331, Houston, Texas.

May 2-4, 1960
National Aeronautical Electronics Conference, Dayton Biltmore Hotel, Dayton, Ohio.
Exhibits: Mr. Edward M. Lisowski, General Precision Lab., Inc., Suite 452, 333 West First St., Dayton 2, Ohio.

May 2-6, 1960
Western Joint Computer Conference, Fairmont Hotel, San Francisco, Calif.
Exhibits: Mr. H. K. Farrar, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco 5, Calif.

May 16-18, 1960
Seventh Regional Technical Conference & Trade Show, Olympic Hotel, Seattle, Wash.
Exhibits: Dr. Frank Holman, Boeing Airplane Co., 10708 39th Ave., S.W., Seattle 66, Wash.

May 24-26, 1960
Armed Forces Communications & Electronics Association Convention and Exhibit, Sheraton-Park Hotel, Washington, D.C.
Exhibits: Mr. William C. Copp, 72 West 45th St., New York 36, N.Y.

June 27-29, 1960
National Convention on Military Electronics, Sheraton-Park Hotel, Washington, D.C.
Exhibits: Mr. L. David Whitelock, BuShips, Electronics Div., Dept. of Navy, Washington, D.C.

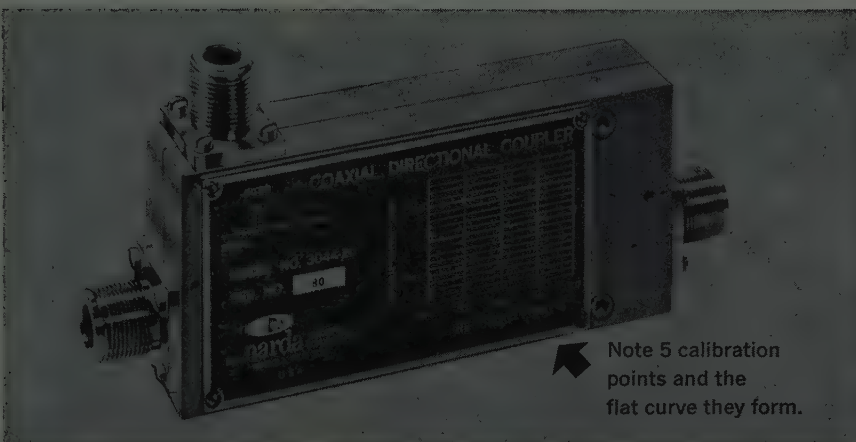
Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department and of course listings are free to IRE Professional Groups.

NEW FROM NARDA

THE INDUSTRY'S FLATTEST COAX COUPLER!

Only 0.2 db variation over full octave!

What more is there to say? The new series of Narda Coaxial Couplers is absolutely the flattest on the market; the specs are here; the prices are here. And you know Narda's reputation for quality! If you need a really flat coupler, contact your Narda representative, or write to us directly.



Note 5 calibration points and the flat curve they form.

Coupling Characteristics

Frequency Response	±0.2 db
Deviation of Mean Value from Nominal	±0.3 db
Calibration Accuracy	±0.1 db

Calibration points at 5 frequencies

Connectors: Series N female; others on special order.

Frequency (mc)	Nominal Coupling	NARDA Model	VSWR Primary, VSWR Secondary	Minimum Directivity (db)	Power Rating FORWARD (watts)	Power Rating REV. (watts)	PK. (kw)	Price
240-500	20	3040-20	1.1/1.2	20	1000	100	10	$200
500-1000	20	3041-20	1.1/1.2	20	1000	100	10	
950-2000	20	3042-20	1.1/1.2	20	1000	100	10	
2000-4000	20	3043-20	1.15/1.2	20	1000	200	10	
4000-8000	20	3044-20	1.2/1.25	17	1000	200	10	
7000-11,000	20	3045-20	1.25/1.3	15	1000	200	10	

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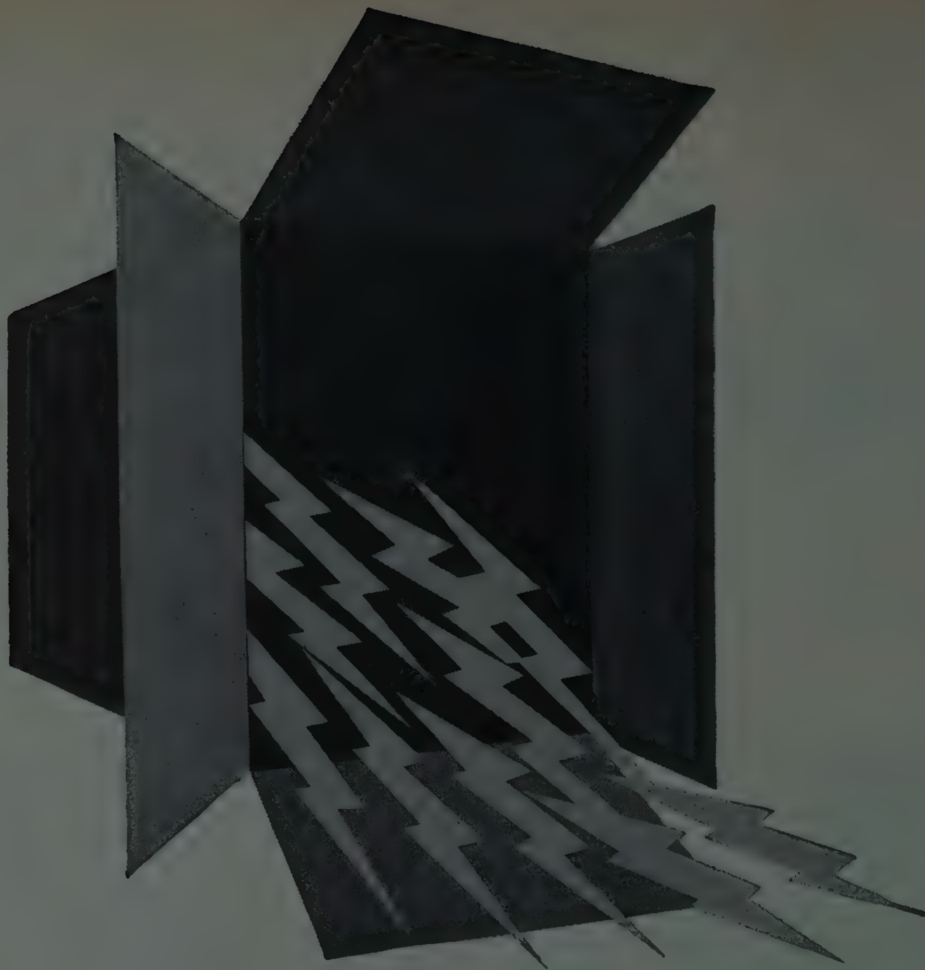

Calendar of Coming Events and Authors' Deadlines*

1959

5th Natl. Communications Symp. (formerly 5th Aero. Comm. Symp.), Hotel Utica, Utica, N.Y., Oct. 5–7.

Ann. Symp. on Interference Reduction, Museum of Sci. and Industry, Chicago Ill., Oct. 6–8.

IRE Canadian Conv., Toronto, Can., Oct. 7–9.

1959 Internatl. Systems Meeting of the SPA, Royal York Hotel, Toronto, Can., Oct. 12–14.

Natl. Elec. Conf., Sherman Hotel, Chicago, Ill., Oct. 12–14.

URSI-IRE Fall Meeting, El Cortez Hotel, Balboa Park, San Diego, Calif., Oct. 19–21.

Semiconductor Sym., Fall Meeting of the Electrochemical Society, Deshler-Hilton Hotel, Columbus, O., Oct. 19–22

East Coast Conf. on Aero. and Nav. Elec., Baltimore, Md., Oct. 26–28.

Michigan Industrial Electronics Exposition, Detroit Artillery Armory, Detroit, Mich., Oct. 28–29.

Electron Devices Mtg., Shoreham Hotel, Washington, D. C., Oct. 29–31. (DL*: Aug. 3, J. Hornbeck, Bell Tel. Labs., Murray Hill, N. J.

Mid. Amer. Elec. Conv., Kansas City, Mo., No. 3–4.

Natl. Conf. on Automatic Control, New Sheraton Hotel, Dallas, Tex., Nov. 4–6.

Radio Fall Mtg., Syracuse, N. Y., Nov. 9–11.

4th Instrumentation Conf., Atlanta Biltmore Hotel, Atlanta, Ga., Nov. 9–11.

12th Ann. Conf. on Elec. Tech. in Med. & Bio., Sheraton Hotel, Phila., Pa, Nov. 10–12.

5th Internatl. Automation Exp., N.Y. Trade Show Bldg., N.Y., N.Y., Nov. 16–20.

5th Conf. on Magnetism and Magnetic Materials Sheraton-Cadillac Hotel, Detroit Mich. Nov. 16–19. (DL*: Aug. 25, J. E. Goldman, Sci. Lab., Ford Motor Co., P.O. Box 2053, Dearborn, Mich.

1959 NEREM (Northeast Electronics Res. & Engng. Meeting), Boston Commonwealth Armory, Boston, Mass., Nov. 17–19.

PGNS 6th Ann. Meeting, Commonwealth Armory, Boston, Mass., Nov. 19–20.

Eastern Joint Comp. Conf., Hotel Statler, Boston, Mass., Dec. 1–3. (DL*: Aug. 15, J. H. Felker, Bell Tel. Labs., Murray Hill, N. J.

4th Midwest Symp. on Circuit Theory, Brooks Mem. Union, Marquette Univ., Milwaukee, Wisc., Dec. 1–2.

* DL = Deadline for submitting abstracts.

(Continued on page 15A)

6th Annual Meeting of PGNS

The IRE Professional Group on Nuclear Science will hold its Sixth Annual Meeting on November 19 and 20 in Boston, Mass.

Special emphasis will be placed on Nuclear Rocket Propulsion. The technical program will include sessions on: Nuclear Science and Space Exploration, Electronics for Plasma Production and Diagnostics, Research Instrumentation for High Energy Nuclear Science, Nuclear Reactor Instrumentation and Control, and Automatic Systems for Nuclear Data Processing.

The meeting will overlap the Northeast Electronics Research and Engineering Meeting (NEREM), which will have complementary technical sessions and exhibits.

For further information please contact: H. F. Stoddard, Atomium Corp., 940 Main St., Waltham 54, Mass.

NAECON Proceedings Now Available

Two hundred copies of the 1959 Proceedings of the 1959 National Aeronautical Electronics Conference (NAECON) are now available. They can be purchased for $5.00 from the Publications Committee, P.O. Box 621, Far Hills Branch, Dayton 19, Ohio. For $11.00 members can also purchase one copy of each back issue of the Conference Proceedings or Digest still available. This offer is good until March 1, 1960, or until the supply is exhausted. At least three of the books will be sent or money will be refunded.

Copies from previous years can also be purchased separately at the following prices:

1958—$5.00	400 copies available
1957—$4.00	600 copies available
1955—$4.00	200 copies available
1954—$4.00	50 copies available.

Long Island IRE Sponsors Radio Talks

The Long Island Section of the IRE began an experiment in cooperation with local high schools in 1956, by making available to them the experience of members of local industry. Through its Student Affairs Committee, a group of 19 lecturers has been made available to math and science classes, clubs and other organized groups. Arrangements are normally made through the activities of a wide-spread group, called High School Representatives, who serve as points of contact with the nearly 30 schools presently served in Nassau and Suffolk counties.

This fall the experiment will take on a new character. The Military Affiliate Radio System (MARS) Eastern Technical Net, which is estimated to reach 14,000 students, technicians, engineers, educators and military reservists in the area east of the Mississippi, will present a series of eight radio talks on successive Sunday afternoons during October and November. The objective of the series is to reach youths who are technically inclined but who may not yet have decided upon a career, to introduce them to the many facets of modern technology, and perhaps to stimulate some of them to become engineers, scientists or technicians.

Presently scheduled are:

October 6 *Engineering—A Career of Opportunity*—G. W. Karlsruher Engineer-in-Charge, Mechanical Engineering Services, Sylvania Electric Products.

October 13 *Careers in Technical Writing*—S. Miles, Vice President, Miles-Sammelson, Inc.

October 20 *Automation in Industry*—T. Dosch, Senior Project Engineer, Reeves Instrument Co.

October 27 *Basic Comparisons of Microwaves, Optics and Infrared*—Bruce A. Woodward, Engineer, Airborne Instruments Lab.

In November the series will include such topics as: Elements of Radar, Guided Missiles and Propulsion Systems, Elementary Particles, Applications of the Atom, and Semiconductors. These MARS broadcasts can be heard from 2 to 4 P.M. prevailing New York time, on 7540 kc and 13,715 kc.

Since suggestions and volunteers are always welcome, those interested may contact J. Kearney, Chairman of the Student Affairs Committee, and G. Krayer, Chairman of the High School Lectures Subcommittee, at Airborne Instruments Laboratory, Melville, N. Y., or J. H. McCoy, Director of the USAF Eastern Technical Net, c/o Office of the Chief, MARS, U. S. Air Force, Tempo T. Building, 6th Street and Adams Drive, Washington 25, D. C.

WJCC Deadline Announced

A call for papers for the 1960 Western Joint Computer Conference next May 3–5 in San Francisco, Calif., has been issued by Howard M. Zeidler of Stanford Research Institute, chairman of the technical program committee.

Following the pattern of the 1959 conference, the program will cover a broad range of subjects of interest to engineers and management in the computer field. Special emphasis will be placed on areas where new planning and new research and development programs are directed toward the growth of computer technology during the next decade.

"We particularly invite papers suggesting concepts and techniques in the newer areas, such as language translation, data retrieval and self-teaching systems," Mr. Zeidler commented. "It is our intention that the conference will serve effectively as a forum for papers and discussions covering the current state of the computer art—both analog and digital."

Submissions to the program are to be prepared on the basis of a thirty-minute delivery, with extra time allowed for discussion. Evaluation will be on the original draft, three copies of which must be directed to Howard M. Zeidler, Stanford Research Institute, Menlo Park, Calif., by November 9.

Joint sponsors of the 1960 WJCC are the IRE, the AIEE and the Association for Computing Machinery.

PGED Holds Annual Meeting

A group of invited papers dealing with the latest advances in semiconductor and microwave components will be presented on the opening day of the Fifth Annual Electron Devices meeting, to be held by the Professional Group on Electron Devices, on October 29 and 30 at the Shoreham Hotel, Washington, D. C.

Dr. J. A. Hornbeck, Bell Telephone Laboratories, Murray Hill, N. J., technical program chairman for the meeting, said that the papers will seek to explain and appraise recent trends in electron tube and solid-state device technology.

The papers will be:

"Tunnel Diodes," Dr. R. N. Hall, General Electric Res. Lab., Schenectady, N. Y.

"Competing Means of Achieving Low Noise," H. Heffner, Electronics Res. Lab., Stanford University, Stanford, Calif.

"Functional Devices," I. M. Ross, Bell Telephone Labs., Murray Hill, N. J.

PGMIL Calls for Papers

The Winter Convention on Military Electronics, sponsored by PGMIL, will be held on February 3–5, 1960, at the Ambassador Hotel, Los Angeles Calif. Technical papers are desired for the sessions of the convention. The following fields of interest are suggested:

Reconnaissance Systems
Guidance and Control
Space Navigation
Ranging and Tracking
Military Implications of Space Age
Data Handling
Inertial Systems
Simulation
Instrumentation
Fire Control and Fuzing
Satellite Electronics
Reliability (Systems)
Electronic Propulsion
Communication Systems

As in the past, a series of classified sessions, under the sponsorship of the military, are planned. For these, papers limited to Confidential will be accepted, each author being responsible for obtaining proper clearances.

A Convention Proceedings is not planned for this convention. Abstracts of all papers will appear in the final convention program. Authors are encouraged to consider their papers for publication in the PGMIL, and also to submit pre-prints at the convention.

All material to be considered for presentation must be sent to Gordon B. Knoob, Motorola, Inc., Military Electronics Div., 1741 Ivar Ave., Hollywood 28, Calif., by November 2, 1959. The Technical Program Committee will notify authors of acceptance of papers by mid-November.

OBITUARIES

Alfred Crossley Senior Member of the IRE, and president and founder of Crossley Associates, Inc., died recently. A pioneer in the radio-electronic field, he was known for his activity in sales and application engineering, as well as for his earlier work in development and design of electronic circuits and components.

After serving as a radio operator in the Navy, he attended the University of North Dakota, where he majored in physics.

In 1917, he re-enlisted in the Navy and was commissioned as Officer in Charge of the Radio Lab., Great Lakes, Ill. Later, he was transferred to Washington, D. C., where he was in charge of the Navy's radio research program. When the Naval Research Lab. was created in 1923, he was in charge of Long Wave Receiver development, and later became Research Director of the Piezo Electric Development Section.


A. Crossley

During this time Mr. Crossley pioneered in the field of crystal controlled oscillators, where he was granted 18 patents. He was also granted 12 patents in the field of powdered iron cores.

In 1928 he became chief engineer of the Steinite Radio Company, and in 1929 he became chief engineer of the Howard Radio Company. In 1933 he left Howard Radio to become a consulting engineer, and in about three years he founded Alfred Crossley and Associates, a sales organization.

Mr. Crossley was active on IRE committees, and served as chairman of the Chicago section in 1935–1936.

❖

Russell H. Varian (A'40–SM'51–F'52), board chairman of Varian Associates, died recently at the age of 61.

Dr. Varian held more than 100 patents in microwave electronics and applied physics and was scientific adviser to several government committees. He was co-inventor of the klystron, for which he received a Wetherill Medal from the Franklin Institute in 1950.


R. H. Varian

Dr. Varian was born in Washington, D. C., on April 24, 1898. He received the B.A. and M.A. degrees in physics in 1925 and 1927, respectively, from Stanford University, Stanford, Calif. In 1943 he received an honorary Doctor of Engineering degree from the Polytechnic Institute of Brooklyn, N. Y.

After receiving the master's degree, Dr. Varian joined the Humble Oil Company, doing geophysical surveys. In 1930 he worked on television with the Farnsworth Television Corp. He went back to Stanford in the late thirties to work on the klystron with his brother, Sigurd, and members of the physics department.

After working on the klystron for a few years with the Sperry Gyroscope Co., Dr. Varian and his brother formed their own company for further work on the klystron in 1948. When the klystron was invented, the *Technological Review* acclaimed it as "the most important advance in radio since the invention of the audion tube in 1906 by Dr. Lee De Forest."

Dr. Varian was a Fellow of the American Physical Society, the California Academy of Science, and the American Association for the Advancement of Science.

Calendar of Coming Events and Authors' Deadlines*

(Continued from page 14A)

PGVC Annual Meeting, St. Petersburg, Fla., Dec. 3–4 (DL*: Jun 30, J. R. Nubauer, RCA, Camden, N.J.)

4th Midwest Symp. on Circuit Theory, Marquette Univ., Milwaukee Wisc., Dec. 1–2.

1960

6th Natl. Symp. on Reliability and Quality Control, Statler-Hilton Hotel, Wash., D.C., Jan. 11–13.

PGMIL Winter Mtg., Ambassador Hotel, Los Angeles, Calif., Feb. 3–5.

1960 Solid State Circuits, Conf., Sheraton Hotel, Phila., Pa., Feb. 10–12. (DL*: Oct. 9, D. L. Finch, Bell Tel. Labs., Murray Hill, N. J.)

IRE National Conv., N. Y. Coliseum and Waldorf-Astoria Hotel, Mar. 21–24.

6th Nuclear Congress, N. Y. Coliseum, New York, N. Y., Apr. 4–8.

Conf. on Automatic Tech., Sheraton-Cleveland Hotel, Cleve., Ohio, Apr. 18–19.

SWIRECO (Southwestern Regional Conference), Houston, Texas, Apr. 20–22.

Natl. Aeronautical Electronics Conf., Dayton, Ohio, May 2–4.

Western Joint Computer Conf., San Francisco, Calif, May 2–6.

PGMTT Natl. Symp., San Diego, Calif., May 9–11.

Electronic Components Conf., Washington, D. C., May 10–12.

7th Reg. Tech. Conf. & Trade Show, Olympic Hotel, Seattle, Wash., May 23–25.

Natl. Conv. on Mil. Elec., Sheraton Park Hotel, Washington, D. C., June 26–28.

Cong. Intl. Federation of Automatic Control, Moscow, USSR, June 25–July 9.

WESCON, Los Angeles Mem. Sports Arena, Los Angeles, Calif., Aug. 23–26.

Natl. Symp. on Telemetering, Washington, D. C., Sept. 18.

Industrial Elec. Symp., Sept. 21–22.

Sixth Natl. Communications Symp., Hotel Utica and Utica Memorial Aud., Utica, N. Y., Oct. 3–5.

Natl. Elec. Conf., Chicago, Ill., Oct. 10–12.

East Coast Conf. on Aero & Nav. Elec., Baltimore, Md., Oct. 24–26.

Electron Devices Mtg., Hotel Shoreham, Washington, D. C., Oct. 27–29.

Radio Fall Mtg., Hotel Syracuse, Syracuse, N. Y., Oct. 31, Nov. 1–2.

Mid-Amer. Elec. Conv., Kansas City, Mo., Nov. 14–16.

13th Ann. Conf. on Elec. Tech. in Med. and Bio., Washington, D. C., Nov.

PGVC Ann. Mtg., Sheraton Hotel, Philadelphia, Pa., Dec. 1–2.

* DL = Deadline for submitting abstracts.

MISCELLANEOUS IRE PUBLICATIONS AVAILABLE

The following issues of miscellaneous publications are available from the Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, New York, at the prices indicated below:

Meetings	Publications	Price per Copy
Aeronautical and Navigational Electronics Conferences	*Proceedings of the 5th Annual East Coast ANE Conference,* held October 27–28, 1958 in Baltimore, Md.	$5.00*
Component Symposia	*Proceedings of the 1954 Electronic Components Symposium,* held May 4–6, 1954 in Washington, D. C.	4.50
	Proceedings of the 1957 Electronic Components Symposium, held May 1–3, 1957 in Chicago, Ill.	5.00
	Proceedings of the 1959 Electronic Components Symposium, held May 6–8, 1959 in Philadelphia, Pa.	7.50
Electronic Computer Conferences	*Proceedings of the Joint AIEE IRE ACM Eastern Conference,* held December 10–12, 1951 in Philadelphia, Pa.	3.50
	Proceedings of the Joint AIEE IRE ACM Eastern Conference, held December 8–10, 1954 in Philadelphia, Pa.	3.00
	Proceedings of the Joint AIEE IRE ACM Eastern Conference, held November 7–9, 1955 in Boston, Mass.	3.00
	Proceedings of the Joint AIEE IRE ACM Eastern Conference, held December 10–12, 1956 in New York, N. Y.	3.00
	Proceedings of the Joint AIEE IRE ACM Eastern Conference, held December 9–13, 1957 in Washington, D. C.	3.00
	Proceedings of the Joint AIEE IRE ACM Eastern Conference, held December 3–5, 1958 in Philadelphia, Pa.	3.00
	Proceedings of the Joint AIEE IRE ACM Western Conference, held March 1–3, 1955 in Los Angeles, Calif.	3.00
	Proceedings of the Joint AIEE IRE ACM Western Conference, held February 7–9, 1956 in San Francisco, Calif.	3.00
	Proceedings of the Joint AIEE IRE ACM Western Conference, held May 6–7, 1958 in Los Angeles, Calif.	4.00
	Proceedings of the Joint AIEE IRE ACM Western Conference, held March 3–5, 1959 in San Francisco, Calif.	6.00
Magnetic Amplifiers Conference	*Proceedings of the Conference on Magnetic Amplifiers,* held April 5–6, 1956 in Syracuse, N. Y.	4.00
Medical Electronics Bibliography	*Bibliography on Medical Electronics,* June 1958	2.50
	Bibliography on Medical Electronics, June 1959 (Supplement no. 1)	2.50
Military Electronics Proceedings	*Proceedings of the 1st National Convention,* held June 17–19, 1957 in Washington, D. C.	5.00†
	Proceedings of the 2nd National Convention, held June 16–18, 1958 in Washington, D. C.	5.00†
	Proceedings of the 3rd National Convention, held June 29–July 1, 1959 in Washington, D. C.	4.00
Reliability and Quality Control in Electronics Symposia	*Proceedings of the 4th National Symposium on Reliability and Quality Control in Electronics,* held January 6–8, 1958 in Washington, D. C.	5.00
	Proceedings of the 5th National Symposium on Reliability and Quality Control in Electronics, held January 12–14, 1959 in Philadelphia, Pa.	5.00
Telemetering Conferences	*Proceedings of the 1953 National Telemetering Conference,* held May 20–22, 1953 in Chicago, Ill.	2.00
	Proceedings of the 1958 National Telemetering Conference, held September 22–24, 1958 in Miami Beach, Fla.	5.00

* IRE Member rate—$3.50
† IRE Member rate—$3.00

Systematic Ionospheric Electron Density Data

Reduction of hourly ionospheric vertical soundings to electron density profiles has become a part of the systematic ionospheric data program of the Central Radio Propagation Laboratory, National Bureau of Standards. Scalings of ionograms for this purpose are being provided by ionosphere stations operated by CRPL and the S. U. Army Signal Corps. For the present, the hourly profile data from one CRPL station, Puerto Rico, are appearing in the monthly CRPL-F Reports, Part A, "Ionospheric Data," which has a limited press-run, and in general is distributed only on an exchange basis. However, compilations of tables of medians of ionospheric data and of tabulations of electron density appearing in this publication may be purchased in booklet form at the price of $1.10 per booklet.

Please make inquiry of

IGY World Data Center A
Airglow and Ionosphere
Central Radio Propagation Lab.
National Bureau of Standards
Boulder, Colo.

These data are in place of the standard ionogram reductions formerly provided by this Station. The very considerable task of scaling the ionograms for this purpose is being undertaken by T. R. Gilliland, Engineer in Charge, Puerto Rico Ionosphere Sounding Station; the computations are performed at the NBS Boulder Laboratories by a group headed by J. W. Wright. Basic conversion of virtual to true heights uses the well-known matrix method developed by K. G. Budden of the Cavendish Laboratory, Cambridge University, programmed for an IBM 650 computer.

The quantities that are given for each hour of each day of the month are: the electron density at each 10 km interval of height, including the maximum electron density proportional to $(foF2)^2$; h_{min}, the height of zero or very low electron density, which is obtained by linear extrapolation of the $N(h)$ curve; h_{max}, the height of maximum electron density, which is determined by fitting a parabola to the upper portion of the profile; and $S(h_{max})$, the integrated electron density between h_{min} and h_{max}.

Two tabulations of arithmetic mean electron densities are also given for every hour. An average for the "undisturbed" ionosphere includes the soundings taken when the magnetic character figure K_p is less than 4+; the remaining data are combined to form the "disturbed" average. The latter may have very little physical significance, because the number of disturbed hours is usually quite small and the behavior of the ionosphere during disturbed hours is not consistent.

Before the averaging process, the individual profiles are extrapolated above h_{max} by a Chapman distribution of 100 km scale height. This assumed model seems to agree well with the few published measurements dealing with the topside profile of the F region. Extrapolation is necessary in order to calculate homogeneous averages near h_{max}, and the average profiles are, in fact, given up to 950 km. Also given are the integrated electron densities estimated to infinity, $S(h_{inf})$; this is an approximation to the total electron content in a column of the ionosphere.

1959 IRE WESCON CONVENTION RECORD

The 1959 IRE Wescon Convention Record, containing all available papers presented at Wescon on August 18–21 in San Francisco, Calif., can now be purchased.

The following important changes have been made in 1959 with regard to the Record:

1) Prices have been reduced by more than 50 per cent.
2) A special reduced rate has been established for members of IRE Professional Groups.
3) The practice of distributing free copies to Professional Group members has been discontinued.

Professional Group members and Affiliates are entitled to purchase the Part sponsored by the Professional Group to which they belong at the special PG rate indicated below. Other Parts may be purchased at the IRE Member rate. There will be no free distribution.

IRE members may purchase any Part at the IRE Member rate indicated below. However, if a member applies for membership in the appropriate Professional Group at the time he places his order, he will be entitled to the PG rate mentioned above.

Nonmembers and libraries may place orders at the Nonmember and the Library rates, respectively, given below. Individuals who apply for IRE membership at the time they place their orders are entitled to the IRE member rates.

Subscription agencies are entitled to the Library rate.

Send orders, with remittance, to the Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y.

IRE WESCON CONVENTION RECORD

Part	Sessions	Subject and Sponsoring IRE Professional Group	Prices for Members of Sponsoring Professional Group (PG), IRE Members (M), Libraries and Sub. Agencies (L), and Nonmembers (NM)			
			PG	M	L	NM
1	3, 8, 13, 31, 37, 42	Antennas & Propagation Microwave Theory & Techniques	$1.00	$1.50	$4.00	$5.00
2	11, 17, 24, 29	Circuit Theory	.80	1.20	3.20	4.00
3	5, 10, 14, 15, 19	Electron Devices	.90	1.35	3.60	4.50
4	4, 9, 22, 27, 30, 36, 41	Automatic Control Electronic Computers Information Theory	1.20	1.80	4.80	6.00
5	20, 25, 26, 28, 34	Aeronautical & Navigational Electronics Human Factors in Electronics Military Electronics Space Electronics & Telemetry	.90	1.35	3.60	4.50
6	1, 2, 12, 16, 18, 33, 40	Component Parts Industrial Electronics Production Techniques Reliability & Quality Control Ultrasonics Engineering	1.20	1.80	4.80	6.00
7	6, 23, 39	Audio Broadcast & Television Receivers Broadcasting Communications Systems	.70	1.05	2.80	3.50
8	7, 32, 35, 38	Instrumentation Medical Electronics Nuclear Science Engineering Management	.80	1.20	3.20	4.00
		Complete Set (8 Parts)	$7.50	$11.25	$30.00	$37.50

Sixth Annual East Coast Conference on Aeronautical and Navigational Electronics

LORD BALTIMORE HOTEL, BALTIMORE, MD., OCTOBER 26–28, 1959

Fourteen sessions concerned with new developments in aircraft and space electronics are scheduled for the sixth annual East Coast Conference on Aeronautical and Navigational Electronics, to be held at the Lord Baltimore Hotel, Baltimore, Md., on October 26–28. Classified sessions and a special student session are innovations of the Conference this year. The classified sessions will be held on October 26 and 27, concurrent with unclassified presentations. Secret clearance is required for attendance at the classified sessions, which are being sponsored by the Air Research and Development Command. Anyone wishing to attend who has not filed special Conference security forms with ARDC should contact T. M. O'Connor, Security Coordinator, Bendix Radio, Baltimore 4, Md., prior to the Conference.

In addition to the technical sessions, there will be a cocktail party Monday evening and a banquet Tuesday evening at the Lord Baltimore. Prizes for the two best papers will be presented at the banquet.

The conference is sponsored by the Baltimore Section and the PGANE. For further information contact G. R. White, Conference Chairman, Bendix Radio, Baltimore 4, Md.

The registration fee for the conference will be $4.00 for IRE members, and $5.00 for non-members. No registration fee will be charged for students.

Monday Morning, October 26

Session 1—Communications

"Application and Design Considerations for Public Address Amplifier in Commercial Aircraft," *C. K. Hartwigsen, Bendix Radio, Baltimore, Md.*

"Selective Calling Equipment," *A. I. Perlin, Bendix Radio, Baltimore, Md.*

"Integration of Radio Equipment Controls for High Performance Aircraft," *W. D. Philips, Bendix Radio, Baltimore, Md.*

"Reliable Communications—The AN/ARC-63," *W. M. Pulford, Bendix Radio, Baltimore, Md.*

"Design Analysis of Airborne Electronic Equipment for Aircraft-Imposed Vibration Loads," *C. Mitropoulos, Sylvania Electronic Systems, Waltham, Mass.*

Session 2(S) Secret—Airborne Radar and Associated Test Equipment (Coordinated by Aircraft Armaments)

"Wide Band AFC System for Ku Band Application" (Confidential), *J. T. Harper and J. L. Redifer, Aircraft Armaments, Inc., Baltimore, Md.*

"A Phase Lock System for Pulsed Radar Signals" (Secret), *H. Raynes, W. C. Cryer, and C. Barrack, Aircraft Armaments, Inc., Baltimore, Md.*

"Design and Evaluation Aspects of a Dynamic Simulator for Ku Band Tracking Radar," *D. Reed, Emerson Electric Mfg. Co., St. Louis, Mo.*

"Electronics Packaging for the Polaris Missile Environment," (Confidential), *B. L. Matonick, General Eledtric Co., Pittsfield, Mass.*

Monday Afternoon

Session 3—Navigation

"Automatic Flight Scheduling in the Volscan Air Traffic Control Central," *J. A. Herndon, Avco Mfg. Corp., Cincinnati, Ohio.*

"A Multi-Bearing Radio Range for Air Navigation," *J. T. Nessmith, Jr., Haddonfield, N. J.*

"An All-Transistor 75 Megacycle 3 Light Marker Beacon Receiver," *J. M. Tewksbury, Bendix Radio, Baltimore, Md.*

"A Bellini-Tosi ADF Loop Using Ferrite," *A. A. Hemphill, Bendix Radio, Baltimore, Md.*

"Accuracy of the Loran-C System," *W. N. Dean, Sperry Gyroscope Co., Great Neck, N. Y.*

Session 4(S) Secret—Advanced Radar Techniques (Coordinated by Westinghouse Air Arm Division)

Moderator: *H. B. Smith, Air Arm Division, Westinghouse Electric Corp., Baltimore, Md.*

"Continuous Wave Radar Investigation," *L. H. O'Neill and R. I. Bernstein, Electronic Res. Lab., Columbia University, New York, N. Y.*

"Decoy Discrimination by Radar," *G. Ralston, et al., Westinghouse Electric Corp., Baltimore, Md.*

"An Analysis of Signal Processing Techniques for Missile Detection Radar," *H. Wainwright and R. Grant, Defense and Electronics Div., Light Military Electronics Dept., General Electric Co., Utica, N. Y.*

"A Discrimination Radar," *G. Weiner and D. Weinfeld, RCA Missile Electronics and Control Dept., Burlington, Mass.*

"Performance Studies of Pulse Doppler Detection Techniques," *S. Thaler and S. A. Meltzer, Airborne Systems Labs., Hughes Aircraft Co., Culver City, Calif.*

"A Long Range Light Weight Detection and Tracking Radar for High Speed Interception," *E. G. Newsom, Sanders Associates Inc., Nashua, N. H.*

Tuesday Morning, October 27

Session 5—Antennas

"Flat Array Antenna for a Doppler Navigation System," *R. E. Willey, Bendix Radio, Baltimore, Md.*

"A Simple Inertialess Scan Antenna Type," *E. Wolff and M. Ringerbach, Westinghouse Electric Corp., Baltimore, Md.*

"Coupling Effects between Antenna Arrays of Different Frequency Bands as a Function of Skew Angle and Spacing on a Cylindrical Missile Body," *S. Isaacson, Martin Co., Orlando, Fla.*

"Combined Antenna-Mixer-Filter Circuit," *E. M. Turner, Wright Air Dev. Center, Wright-Patterson AFB, Ohio.*

"Antennas for Microwave Radiometry," *H. Warren Cooper, Westinghouse Electric Corp., Baltimore, Md.*

"A Yagi Adcock System for Satellite Tracking," *H. W. Ehrenspeck and W. J. Kearns, Air Force Cambridge Res. Center, Bedford, Mass.*

Session 6(S) Secret—Design of a Large Scale Electronically Steerable Array Radar (Coordinated by Bendix Radio, Baltimore, Md.)

"Outline of an ESAR System," *C. S. Lerch, Jr., Bendix Radio, Baltimore, Md.*

"System Analysis and Design," *F. C. Ogg, Bendix Radio, Baltimore, Md.*

"Electronic Beam Steering," *N. F. Pribble, Bendix Radio, Baltimore, Md.*

"Post Amplifier Beam Forming," *D. B. Strang, Sanders Assoc., Nashua, N. H.*

"Components for Phased Arrays," *A. B. Meador, Jr., Bendix Radio, Baltimore, Md.*

"Monitoring Performance of Phased Arrays," *M. Falkowitz, Sylvania Electric Co., Waltham, Mass.*

Tuesday Afternoon

Session 7—Space Problems

"Tracking of Satellites," *W. W. Gerbes and O. E. Kerr, Air Force Cambridge Res. Center, Bedford, Mass.*

"Diagrammatic Methods for Coordinate Conversion," *S. A. Zadoff, Radio Receptor Co., Brooklyn, N. Y.*

"Relative Motion of Two Bodies with Small Velocity Differences on Gravitational Field," *W. Furth, The Martin Co., Baltimore, Md.*

"Simplification of Certain Orbit Characteristics by Use of $e^{i\sigma}$," *R. C. Spencer, The Martin Co., Baltimore, Md.*

"A Pure Inertial Attitude Reference System for Orbital Vehicles," *R. L. Gordon, Sperry Gyroscope Co., Great Neck, N. Y.*

"Gyro Configuration Requirements for Optimum Accuracy," *J. B. Chatterton, Moeller Instr. Co., Richmond Hill, New York, N. Y.*

Session 8(S) Secret—CW Radar Techniques (Coordinated by The Martin Co.)

Moderator: *G. J. Strickroth, The Martin Co., Baltimore, Md.*

"High Speed Switching Matrix," *M. Lindenthal, The Martin Co., Baltimore, Md.*

"Low Noise Transistor Amplifier," *A. Bourget, The Martin Co., Baltimore, Md.*

"Antenna System for Airborne CW Radar" (Secret), *H. C. Hanks, Jr., The Martin Co., Baltimore, Md.*

"Sea State Indicator," *J. Williams, The Martin Co., Baltimore, Md.*

"A Velocity Tracking Communication

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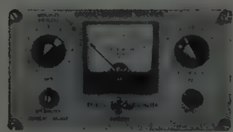

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System" (Unclassified), *J. Albert and H. Rosenblatt, The Martin Co., Baltimore, Md.*

Wednesday Morning, October 28

Session 9—Human Factors

Moderator: *S. Hasler, The Martin Co., Baltimore, Md.*

"The Design Engineer and Human Engineer—A Coordinated Approach," *D. R. Nicklas and D. Petersen, The Martin Co., Baltimore, Md.*

"Design of Integrated Cockpit," *G. J. Fox and C. Seitz, Grumman Aircraft Co., Beth Page, N. Y.*

"Visibility of Cockpit Cathode Ray Tube Naviagation Displays," *C. T. Goldsmith and C. Seitz, Grumman Aircraft Co., Beth Page, N.Y.*

"Reliability and Man in Space," *R. D. Sorkin and M. A. Grodsky, The Martin Co., Baltimore, Md.*

"Consideration for Electronic Equipment for Space Suit," *R. K. Cassatt, II, F. J. Conley, Jr., and M. A. Grodsky, The Martin Co., Baltimore, Md.*

"Maintenance of Electronic Equipment in Space," *M. A. Grodsky, The Martin Co., Baltimore, Md.*

Session 10—Doppler

"A Doppler Navigational Radar Utilizing New Techniques," *B. L. Cordry, Bendix Radio, Baltimore, Md.*

"Applications of Doppler Radar to the Navigation Problem," *C. C. Bath, Bendix Radio, Baltimore, Md.*

"Doppler Navigator Accuracy by Photogrammetric Measurement," *G. Cooper, Raytheon Co., Wayland, Mass.*

"A New Doppler Radar Frequency Tracker," *E. O. Kirner, Bendix Radio, Baltimore, Md.*

"A Hybrid Airborne Computer for Doppler Application," *T. Owens and C. Christiansen, Bendix Radio, Baltimore, Md.*

"A Transistorized Frequency Summing and Differencing Device Capable of Coherent Algebraic Manipulation of the Four Data Frequencies in a Doppler Radar Computer," *W. G. Gunkel and C. L. Christiansen, Bendix Radio, Baltimore, Md.*

Session 11—Radar

"Radar Cartography," *D. Levine, Consulting Engineer, Glendale, Ariz.*

"A New Technique for Measuring Operational Radar Antenna Patterns," *A. E. F. Grempler, Bendix Radio, Baltimore, Md.*

"Active Radar Target Area Cross-section Enhancement," *A. G. Cheney, Convair, San Diego, Calif.*

"An Automatic, Quantitative and Qualitative Performance Test Set," *H. D. Gulnac, Motorola, Inc., Phoenix, Ariz.*

"Spherical Radar Reflectors with High-Gain Omnidirectional Response," *H. E. Schrank, Westinghouse Electric Corp., Baltimore, Md.*

"CW Velocity Track Loop Simulation by DC Electronic Analogue Computer," *S. Baida, T. A. Priscilla, Westinghouse Electric Corp., Baltimore, Md.*

Wednesday Afternoon

Session 12(H)—Panel Discussion: Opportunities for Engineers—Today and Tomorrow

Moderator: *G. A. Pitt, Vice-President of The Johns Hopkins University and Hospital, Baltimore, Md.*

Speakers: *W. W. Bender, Vice-President, Res. Inst. for Advanced Study, The Martin Co., Baltimore, Md.*

F. Hamburger, Jr., Chairman, Elec. Eng. Dept., The Johns Hopkins University, Baltimore, Md.

C. W. King, Chief, Civilian Personnel Div., ARDC.

G. D. Lobingier, Manager, Educational Center, Westinghouse Electric Corp., Pittsburgh, Pa.

Gen. L. G. Smith, Superintendent of Electric Distribution Dept., Baltimore Gas and Electric Co., Baltimore, Md.

J. L. Rogers, Director of Placement, The Johns Hopkins University, Baltimore, Md.

Session 13—Panel Discussion: The Air Force Applied Research Planning Document on Computer and Data Processing Techniques

Moderator: *Col. C. F. Brown, Jr., Headquarters ARDC.*

G. B. Fallon, The Martin Co., Baltimore, Md.

Dr. L. F. Jones, Westinghouse Electric Corp., Baltimore, Md.

J. Martin, Bendix Aviation Corp., Baltimore, Md.

J. L. VanMeter, Westinghouse Electric Corp., Baltimore, Md.

Dr. M. Weik, Ballistics Research Labs., Aberdeen Proving Ground, N. Mex.

Session 14—Circuits and Techniques

"Design and Evaluation of Space Transmission Systems Using Computer Simulation Techniques," *D. R. J. White, American Machine and Foundry Co., Alexandria, Va.*

"Hit-Miss Detector," *J. Machlis, Radioplane, Northrop Corp., Van Nuys, Calif.*

"Pedestal Free Switches," *S. L. Anema, Bendix Radio, Baltimore, Md.*

"A Transistorized True Integrator," *W. H. Jory, Bendix Radio, Baltimore, Md.*

"Accurate Diode Rate Counters and Some Applications," *J. Collins, Raytheon Co., Maynard, Mass.*

"Impact of Electronic Costs on Weapon Systems Evaluation," *R. E. Winslow, Boeing Airplane Co., Seattle, Wash.*

National Automatic Control Conference

Sheraton-Dallas Hotel, Dallas Tex., November 4–6, 1959

The National Automatic Control Conference is sponsored by the PGAC with the participation of the AIEE, the Instrument Society of America, and the PGIE; and the cooperation of the American Society of Mechanical Engineers and the Electrical Engineering Department of Southern Methodist University.

The registration fee is $5.00; full-time students and faculty, $1.00. There will be no advance registration. Registration will begin at the Conference on November 4, 7:30 A.M.

Abstracts of all technical papers will be available at the Registration Desk. Anyone desiring an advance copy of abstracts may send a self-addressed stamped envelope to M. L. Barnett, Apt. 208, 6255 Oram St., Dallas, Tex.

The Feedback Control Systems Committee of the AIEE (with other cooperating groups) is sponsoring a "Control System Components Conference," at the Sheraton-Dallas Hotel, in parallel with the second and third day of the conference. Their technical sessions, marked "CSCC," are included in the program listings below in abbreviated form. Complete information may be obtained from D. D. Pidhayny, Ramo-Wooldridge, P.O. Box 90534, Airport Station, Los Angeles 45, Calif. A single registration will cover both conferences.

Dr. Albert C. Hall, automatic control pioneer and currently Director of Research at the Martin Co., Denver, Colo., will speak at a combined National Automatic Control Conference-Control System Components Conference dinner meeting, November 5, 7:30 P.M., in the Sheraton-Dallas Hotel. Because the number of tickets available is limited, it is urged that advance reservation be made by sending $7.50 per ticket to Prof. F. W. Tatum, Electrical Engineering Dept., Southern Methodist University, Dallas, Tex. Checks should be made payable to the Institute of Radio Engineers. The tickets will be held at the Registration Desk.

Wednesday Morning, November 4

Session 1—General

Chairman: *J. E. Ward, PGAC Chairman, MIT, Cambridge, Mass.*

Welcoming Address: *J. E. Jonsson, Chairman of the Board of Texas Instruments, Inc., and Past President of Dallas Chamber of Commerce.*

"Fundamental Theory of Automatic Linear Feedback Control Systems," *I. M. Horowitz, Hughes Aircraft Co., Culver City, Calif.*

"General Approach to Control Theory Based on the Methods of Lyapunov," *R. E. Kalman, RIAS, Inc., Baltimore, Md., and J. E. Bertram, IBM Res. Center, Yorktown Heights, N. Y.*

"The Impact of Information Conversion on Control," *H. Chestnut and W. Mikelson, General Electric Co., Schenectady, N. Y.*

Wednesday Afternoon

Special Session—Control Problems of the Space Age

Chairman: *J. M. Salzer, Ramo-Wooldridge, Los Angeles, Calif.*

"Controlled Propulsion," *K. K. Dannenberg, Jupiter Project Director, Army Ballistic Missile Agency.*

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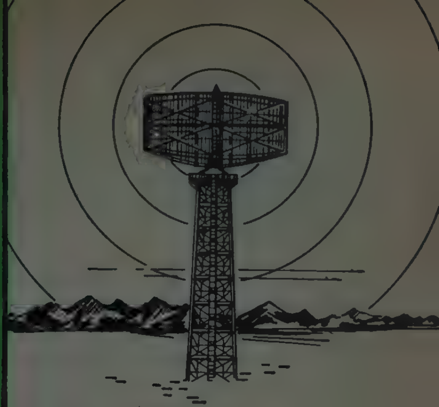

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"Attitude Control of Space Vehicles," *Dr. C. R. Gates, Chief of Guidance Systems Analysis, Jet Propulsion Lab.*

"Tracking and Path Control," *Dr. R. C. Booton, Jr., Manager, Guidance and Navigation Dept., Space Technology Labs., Inc.*

"Control of the Human Environment," *Dr. Paul Webb, Consultant.*

Thursday Morning, November 5

Session 2—Nonlinear Control Theory

Chairman: *F. W. Tatum, Electrical Engineering Dept., Southern Methodist, Dallas, Tex.*

"Signal Stabilization of Self-Oscillating Systems," *R. Oldenburger, Purdue Univ., and T. Nakada, Tokyo Institute of Technology.*

"A Root Locus Method for the Analysis of Nonlinear Servomechanisms," *M. J. Abzug, Douglas Aircraft Co., Inc., El Segundo, Calif.*

"Some Nonlinear Control Techniques Novel to Control Engineers Employed by a Biological Control System," *M. Clynes, Rockland State Hospital, Orangeburg N.Y.*

"On the Analysis of Bi-Stable Control Systems," B. E. Amsler and R. E. Gorozdos, *Applied Physics Lab., Johns Hopkins University, Silver Spring, Md.*

"Effect of Power Source Regulation on the Response of a Control System Amplifier," *R. J. Kochenburger, U. of Connecticut, Storrs.*

Session "CSCC-1"—Magnetic Components—Transformers

Session "CSCC-2"—Instrumentation

Thursday Afternoon

Session 3—Automatic Control Devices and Systems

Chairman: *A. R. Teasdale, Temco Aircraft Corp., Dallas.*

"Pendulous Velocity Meter Control Synthesis," *S. G. Shutt, Autonetics, Div. of North American Aviation, Inc., Downey, Calif.*

"The Analysis of Demodulating Compensating Networks," *G. J. Murphy and J. F. Egan, Northwestern Univ., Evanston, Ill.*

"Mathematical Models for Computer Control Systems," *T. M. Stout, Thompson-Ramo-Wooldridge Products Co., Los Angeles, Calif.*

"Multi-Loop Temperature Control System for Fluid Dynamics Facility with Long Transport Delays," *G. J. Fiedler and J. J. Landy, Sverdrup and Parcel Engineering Co., St. Louis, Mo.*

"Some Linear and Nonlinear Aspects of Hot Gas Servo Design," *R. V. Halstenberg, Convair, San Diego, Calif.*

Session 4—Control System Synthesis and Optimization (Organized by ASME)

Chairman: *C. F. Taylor, Daystrom, Inc., La Jolla, Calif.*

"Topological Techniques for the Solution of Multi-Loop Sampled Systems," *R. Ash, W. H. Kim, and G. M. Kranc, Columbia Univ., New York, N. Y.*

"Synthesis of Third Order Contactor Control Systems," *Irmgard Flügge-Lotz, Stanford Univ., Stanford, Calif.*

"On After-End-Point Motions of General Discontinuous Control Systems and Their Stability," *P. Seibert, RIAS, Inc., Baltimore, Md.*

"On the General Theory of Control Systems," *R. E. Kalman, RIAS, Inc., Baltimore, Md.*

"On Optimal Computer Control," *J. E. Bertram and P. E. Sarachik, IBM Research Center, Yorktown Heights, N. Y.*

"The Second Method of Lyapunov in the Analysis and Optimization of Control Systems: Sampling Systems," (presentation by title only) *R. E. Kalman, RIAS, Inc., Baltimore, Md., and J. E. Bertram, I.B.M. Research Center, Yorktown Heights, N. Y.*

Session "CSCC-3"—Magnetic Components—Amplifiers

Friday Morning, November 6

Session 5—Automatic Flight Control

"Adaptive Flight Control," (ISA paper) *O. H. Schuck, Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.*

"Electronic Gain Control in Automatic Flight Control Systems," *W. Henn and E. L. Boronow, Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.*

"Electronic Memory in Automatic Flight Control Systems," *D. Blanvett and A. S. Robinson, Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.*

"Pulse Controlled Integration in Automatic Flight Control Systems," *A. S. Robinson, Eclipse Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.*

"Reaction Wheel Attitude Control for Space Vehicles," *R. W. Froelich and H. Patapoff, Space Technology Labs., Inc., Los Angeles, Calif.*

Session "CSCC-4"—Hydraulic Components

Friday Afternoon

Session 6—Control System Design Techniques

Chairman: *J. H. Mulligan, Jr., Electrical Engineering Dept., New York Univ., N. Y.*

"D-Decomposition Analysis of Automatic Control Systems," (ISA paper) *R. W. Lunskron, Martin Co., Orlando, Fla., and T. J. Higgins, U. of Wisconsin, Madison.*

"Optimization of the Adaptive Function by the Z-Transform Method," (AIEE paper) *S. S. L. Chang, New York Univ., N. Y.*

"Application of Pole-zero Concepts to Design of Sampled Data Systems," *D. P. Lindorff, U. of Connecticut, Storrs.*

"Synthesis of Feedback Systems with Specified Open-Loop and Closed-Loop Poles and Zeroes," *W. E. Carpenter, Space Technology Lab., Los Angeles, Calif.*

"Calculating Zeroes of Functions Arising in Various Control System Problems," (AIEE paper) *W. R. Evans, Autonetics, Div. of North American Aviation, Downey, Calif.*

Session 7—Random Processes in Control Systems

Chairman: *H. Freeman, Sperry Gyroscope Co., Great Neck, N. Y.*

"Random Sampling: Its Effect on Spectral Density," *A. R. Bergen, U. of California.*

"A Procedure for Synthesizing Linear Time-Varying Shaping Filters for Generating Non-stationary Random Outputs," (ISA paper) *M. M. Sondhi and T. J. Higgins, U. of Wisconsin, Madison.*

"Spectral Characterization of Control System Nonlinearities," *R. B. McGhee, Hughes Aircraft Co., Culver City, Calif.*

"Techniques for the Optimum Synthesis of Multipole Control Systems with Random Processes as Inputs," *C. T. Leondes and H. S. Hsieh, U. of California (Los Angeles).*

"Predictor Relay Servos with Random Inputs," *T. R. Benedict, Cornell Aeronautical Labs., Buffalo, N.Y.*

Session "CSCC-5"—Electromechanical Components

Fourth IRE Instrumentation Conference and Exhibit

BILTMORE HOTEL, ATLANTA, GA., NOVEMBER 9–11, 1959

The Fourth IRE Instrumentation Conference, sponsored by the PGI and the Atlanta Section of the IRE, will be held in Atlanta, Ga., November 9–11, 1959, at the Atlanta Biltmore Hotel. Technical sessions will include papers dealing with Reliability, Measurements, Data Gathering and Display, Nuclear Instrumentation, Semiconductor Applications, and Missile Satellite Instrumentation. The exhibit will include a variety of electronic equipment used in Instrumentation, Data Gathering, and related areas. The annual banquet on Tuesday evening will feature a prominent guest speaker.

Advance registration fee for the Conference is $3.00 for IRE members and $4.00 for nonmembers. At-the-door registration will be $4.00 for IRE members and $5.00 for nonmembers. No registration fee will be charged for students. To register in advance send a check made payable to the Atlanta Instrumentation Conference, c/o The School of Electrical Engineering, Georgia Institute of Technology, Atlanta, Ga.

Monday Morning, November 9

Reliability

"Airborne Electronics—Reliability 1959," *H. J. Redgrave, Air Arm Div., Westinghouse Electric Corp., Baltimore, Md.*

"Electronic-Type Resistor Reliability Measurements Study," *B. F. Lathan, H. G. Hamre and R. M. Bergslien, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.*

"Instrumentation for Complex Signal Environmental Testing," *D. Krueger and B. G. Herlt, Jr., HRB-Singer, Inc., State College, Pa.*

"The Economics of Test Packages," *M. A. Dean, Sperry Gyroscope Co., Great Neck, N. Y.*

Monday Afternoon

Measurements

"Problems Associated with Precise Determination of the Index of Refraction of the Earth's Atmosphere," *A. M. Bush, Electronics and Armament Systems, Lockheed Aircraft Corp., Marietta, Ga.*

"Insulation Resistance Measurements Using an Electronic Electrometer up to 10^{18} ohm," *B. Bortoletto, Pirelli Factory, Naples, Italy.*

"A Thermistor Bridge for Measuring Low-Level RF Voltage and Power," *R. B. Schulz, L. J. Greenstein, and D. Fryberger, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.*

"Millimicrosecond Pulse Instrumentation for Microwaves," *J. T. Tippett, Department of Defense, Washington, D. C.*

"An Improved Sing-Around System for Ultrasonic Velocity Measurements," *R. L. Forgacs, Scientific Lab., Ford Motor Co., Dearborn, Mich.*

Tuesday Morning, November 10

Data Gathering and Display

"Livermore Multibeam Cathode Ray Tube," *L. Mancebo, D. Stewart and G. A. Leavitt, Lawrence Radiation Lab., U. of California, Livermore, Calif.*

"Automatic Digital Data Error Recorder," *E. J. Hofmann, MIT Lincoln Lab., Lexington, Mass.*

"Time Correlated Digital Data System on the USAF Gulf Test Range," *J. B. Somerset and R. D. Somerset, ARDC, Eglin AFB, Fla.*

"A Mobile General-Purpose Data Processing System," *C. Pilnick, Consolidated Avionics Corp., Westbury, N. Y.*

Tuesday Afternoon

Nuclear Instrumentation

"Transistorized Instrumentation for Nuclear Measurement Systems," *R. C. Ryan and W. M. Trenholme, General Electric Co., West Lynn, Mass.*

"Data Storage and Display for Nuclear Reactors," *A. Pearson, Canadian Atomic Installation, Chalk River, Ontario.*

"A Direct Reading Fast Neutron Dosimeter," *J. T. DeLorenzo and H. N. Wilson, Oak Ridge National Lab., Oak Ridge, Tenn.*

"Pulse Neutron Sources and Applications," *B. J. Carr, The Kaman Aircraft Corp., Albuquerque, N. M.*

"Graphite-Carbon Dioxide 4CC Ion Chamber," *C. C. Hall, and S. D. Johnson, Lockheed Aircraft Corp., Dawsonville, Ga.*

Wednesday Morning, November 11

Semiconductor Applications

"Radiation Tracking Transducer," *I. Weiman, Electro-Optical Systems, Inc., Pasadena, Calif.*

"A Precise Method of Transistor Characterization at VHF," *T. Uchida, General Electric Co., Syracuse, N. Y.*

"A Transistorized Telerecording Bathythermometer," *D. W. Boensel, Consultant to Hytech Corporation, Inglewood, Calif.*

"A Diode Matrix Commutator with Transistor Flip-Flop Switching Control," *S. L. Robinette, Jr., Engineering Experiment Station, Georgia Inst. of Tech., Atlanta, Ga.*

"A Silicon Transistorized Scaling Stage with 0.05 Microsecond Resolution Time," *L. B. Gardner, Litton Ind., Los Angeles, Calif.*

Wednesday Afternoon

Missile and Satellite Instrumentation

"Basics of Biological Instrumentation," *M. Hanish, Litton Ind., Los Angeles, Calif.*

"Telemetry Receiving Antennas at Cape Canaveral," *H. A. Roloff, RCA Service Company, Patrick Air Force Base, Fla.*

"A Compact Frequency Translator For Use With The Ammonia Maser," *W. K. Saunders, Ordnance Corps., Diamond Ordnance Fuze Labs., Washington, D. C.*

"Analysis of Axial Accelerometer Capability to Provide Trajectory Data on Ballistic Re-Entry Vehicles," *L. E. Foster, Missile and Space Vehicle Department, General Electric Co., Philadelphia, Pa.*

"Elimination of Cross-Coupling Errors in Rate Cyro Data," *P. Mosner, Missile Electronics and Controls Department, RCA Burlington, Mass.*

Radio Fall Meeting

HOTEL SYRACUSE, SYRACUSE, N.Y., NOVEMBER 9–11, 1959

The Radio Fall Meeting, sponsored by the EIA Engineering Department and the IRE Committee on Professional Groups, will be held at the Hotel Syracuse, Syracuse, N. Y., November 9–11. A Stag Party, a cocktail party and a dinner, with D. R. Hull, President of Electronic Industries Assoc., as Toastmaster, will be included in the three-day meeting.

Monday Morning November 9

EIA Engineering Department Session

Chairman: *J. R. Whitney.*

"National Stereophonic Radio Committee," *C. G. Lloyd, Chairman, "NSRC," General Electric Co.*

"Value Analysis and Engineering Activities," *R. S. Mandelkorn, Chairman, "VE" Staff Committee, Lansdale Tube Co.*

"Parts Standardization," *L. Podolsky, Chairman, "P" Panel, Sprague Electric Co.*

Monday Afternoon

Reliability and Quality Control Session

(Arranged by the IRE Professional Group on Reliability and Quality Control)

Chairman: *J. R. Steen.*

"Reliability of Germanium Transistors," *O. H. Somers, Raytheon Manufacturing Co.*

"Aspects of Reliability in Transistorized Home Radios," *J. J. Corning, General Electric Co.*

"Proper Application of Transistors in Battery Portable Receivers," *R. M. Cohen, RCA.*

"Automation for Quality Control Testing of Electronic Tubes," *R. A. McNaughton, Sylvania Electric Products, Inc.*

Tuesday Morning, November 10

Electron Tube Session

Chairman: *W. Massey.*

"New Oscillator—Mixer Circuits for TV and FM Tuners," *E. H. Hugenholtz, Amperex Electric Corp.*

"Composit Base Metal for Oxide Coated Cathode," *W. T. Millis, General Electric Co.*

"Sarong Cathode," *D. R. Kerstetter, Sylvania Electric Products, Inc.*

"6EV5—New VHF Tetrode," *R. Pear, Westinghouse Electric Corp.*

"Nuvistor Triode as an RF Amplifier in TV Receivers," *L. Barr, RCA.*

Tuesday Afternoon

Transistorized TV Tuner Session

Chairman: *C. D. Simmons.*

"Design Notes on a Transistorized VHF TV Tuner," *V. Mukai, General Instrument Co.*

"Transistorized TV Tuners," *K. Whitteg, Standard Coil Co.*

"Panel Discussion on Transistorized TV Tuners," *authors of above papers and the session chairman.*

Wednesday Morning, November 11

Transistorized TV Session

"Linearization of Transistorized Vertical Deflection," *R. B. Ashley, General Electric Co.*

"A Transistorized TV Sound System," *L. J. Mattingley, Motorola, Inc.*

"Transistorized Battery Operated Portable TV Receiver," *A. R. Curll, Philco Corp.*

"Transistorized TV IF Amplifier," *J. G. Humphrey, General Electric Co.*

"Transistorized Sync Circuit," *C. D. Simmons and C. R. Gray, Lansale Tube Co.*

Wednesday Afternoon

Transistorized Receiver Session

Chairman: *H. Lowry.*

"Integrated AM/FM Transistorized Portable Receiver," *H. van Abbe, Amperex Electronics Inc.*

"A Transistorized AM/FM Receiver Using Drift Transistors," *R. A. Santilli and H. Thanos, RCA.*

"Transistorized Automobile Radios Employing Drift Transistors," *R. A. Santilli and C. F. Wheatly, RCA.*

"Solar Power Supplies for Transistorized Radios," *J. K. Hoffman, Semiconductors Inc.*

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Twelfth Annual Conference on Electrical Techniques in Medicine and Biology

SHERATON HOTEL, PHILADELPHIA, PA., NOVEMBER 10–12, 1959

The 12th Annual Conference on Electrical Techniques in Medicine and Biology, sponsored by the PGME, the American Institute of Electrical Engineers and the Instrument Society of America, will be centered around medical and biological uses of radiation of all wavelengths. Sessions will be held on Ultraviolet, Microwaves, Infrared and Ultrasonics, as well as on more general subjects of interest.

The conference will also feature an exhibit of the latest electromedical equipment such as cardiac phonocatheters, fetal heart pickups and pulse rate monitors.

Another feature will be a series of planned tours to laboratories in the area, including the Johnsville Aero-Medical Acceleration Lab. (USN), The Institute for Cancer Research, the Electromedical Laboratory and the Johnson Foundation at the University of Pennsylvania, the Air Crew Equipment Lab. (USN) and RCA Labs. in Princeton, N. J.

This year, all conference registrants will receive a complete digest of technical papers.

While the program has not yet been completed, a partial list of the papers follows:

Ultraviolet

Chairman: *J. Schultz, Inst. for Cancer Res. Philadelphia, Pa.*

"General Problems of Absorption Measurements in Living Cells," *B. O. Thorell, Karolinska Inst., Stockholm, Sweden.*

"The Measurement of the Absorption of Ultraviolet Radiation by Cell Structures," *G. T. Rudkin, Inst. for Cancer Res., Philadelphia, Pa.*

"Effects of Ultraviolet Radiation on Living Cells," *M. R. Zelle, AEC.*

"Use of Scanning Techniques for Ultraviolet Irradiation Studies in Living Cells," *P. O. B. Montgomery, Southwestern Medical School, U. of Texas, Dallas.*

"Flying-Spot Scanning Techniques in Microscopy," *L. L. Hundley, Southwestern Medical School, U. of Texas, Dallas.*

"The Nature of Radiation Effects on the Specimen in UV Microscopy of Living Cells," *J. J. Freed and J. L. Engle, Inst. for Cancer Res., Philadelphia, Pa.*

"Measurement of the Reduction Rate of Metabolic Action in Living Cells by Ultraviolet Television Microscopy and Oscilloscopy," *G. L. Williams and G. G. Vurek, Nat. Insts. of Health, Bethesda, Md., and R. G. Neuhauser, RCA, Princeton, N. J.*

Microwaves

Chairman: *G. M. Knauf USAF (MC) Patrick A.F.B., Fla.*

"Biological Effects of Microwaves Radiation," *G. M. Knauf, Patrick AFB., Fla.*

"Current Research on Biological Effects of Radiation," *T. S. Ely, Div. of Biology and Medicine, AEC.*

"Review of Research on Microwaves Damage to the Eye," *R. L. Carpenter, Tufts University, Medford, Mass.*

"Controlled Brain Lesions made with Radio Frequency Power" *S. Aronov, Massachusetts General Hospital, Boston, Mass.*

Infrared

Chairmen: *J. D. Hardy, U. of Pennsylvania and E. Hendler, U. of Pennsylvania and Naval Air Crew Equipment Lab., Philadelphia.*

"Radiant Heat Sources Employed in Thermal Burn Studies," *J. A. Carter, W. L. Derksen, and T. I. Monahan, Naval Material Lab., Brooklyn, N. Y.*

A trio of papers by W. L. Derksen, T. I. Monohan, and G. P. deLhery, Naval Material Lab., Brooklyn, N. Y.

"Skin Stimulants Employed in Thermal Burn Studies";

"Measurement of Temperature in Thermal Burn Studies";

"Some Thermal and Optical Properties of Rat Skin."

"Use of Inanimate Simulants in Evaluating Thermal Energy Transfer through Cloth and Skin," *N. V. Chen, Fuels Res. Lab., M.I.T., Cambridge, Mass.*

"The U. S. Army Quartermaster Solar Furnace," *J. M. Davies, QM Res. and Eng. Command, U. S. Army.*

"Effective Stimulus for the Warmth Receptor in Man," *J. D. Hardy and E. Hendler, U. of Pennsylvania, Philadelphia.*

Ultrasonics

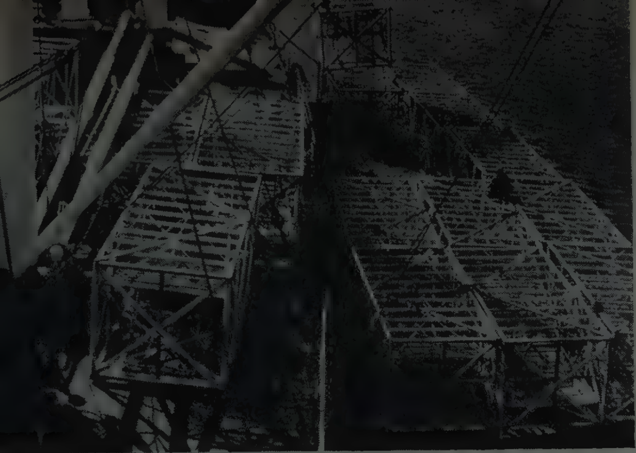
Chairman: *W. J. Fry, U. of Illinois, Urbana.*

"Absorption of Ultrasound in Biological Materials," *E. L. Carstensen, Biophysics Branch, Camp Detrick, Md.*

"Ultrasonic Visualization of Soft Tissue Structure," *D. H. Howry, U. of Colorado Medical Center, Boulder.*

"High Intensity Ultrasound in Basic Neurological Investigation and Human Neurosurgery," *F. J. Fry, U. of Illinois, Urbana.*

"Interaction of Ultrasound and Calculi," *H. H. Zinsser, College of Physicians and Surgeons, Columbia Univ., New York, N. Y.*



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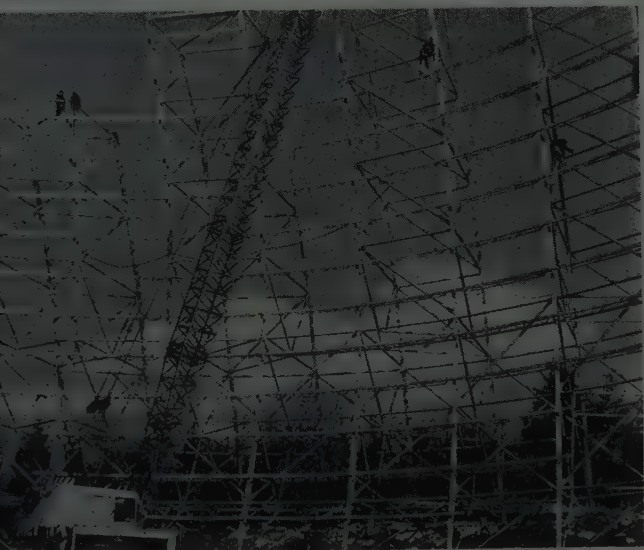

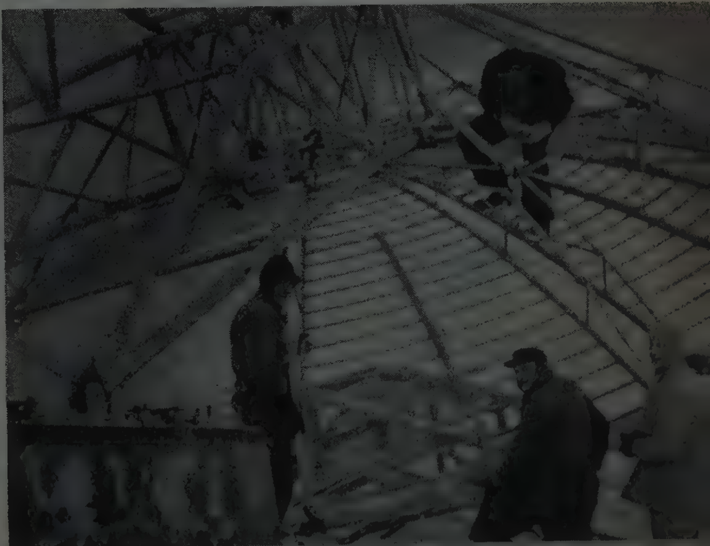

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30.5 Methods of Measurement of Systems Transmission Characteristics

30.6 Methods of Measurement of Microphone Characteristics

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30.7 Methods of Measurement of Loudspeaker Characteristics

30.8 Methods of Measurement of Recording and Reproducing Transducer Characteristics

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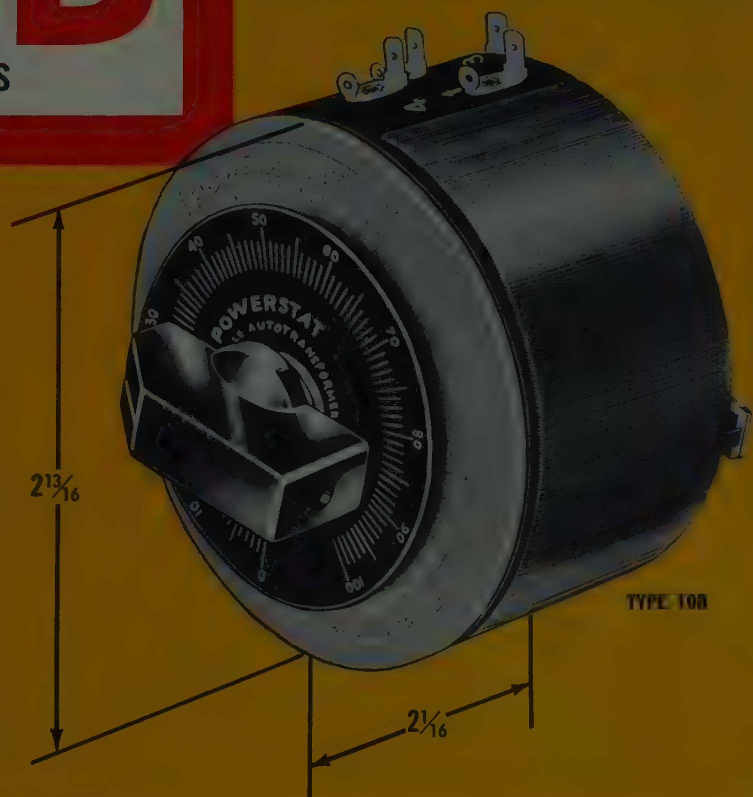
SERIES	10B	20	116-216	117-217	126-226	136-236	1156C-1256C	H-C
AMPERES	1.75	3.0	7.5 3.0	10.0 4.0	12.5 6.0	20.0 9.0	45.0 28.0	200 and up

the NEW 10B SERIES

POWERSTAT®
variable transformers



40% INCREASE IN RATING . . .
NO INCREASE IN PRICE!
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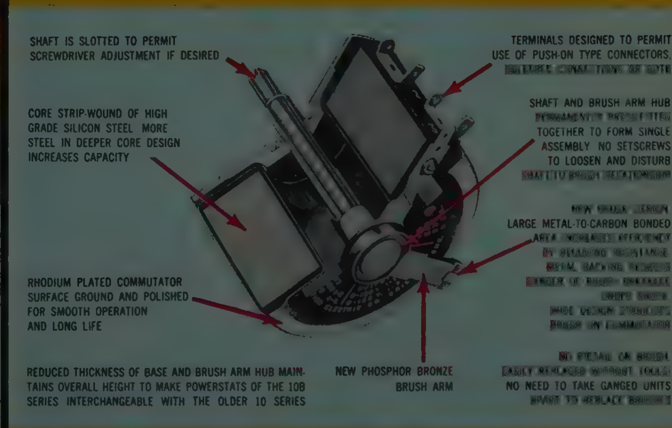
POWERSTATS of the new 10B Series incorporate the most up-to-date variable transformer design refinements to provide the highest ratings and performance characteristics in their price and size range. Separate ratings are given for constant-impedance and constant-current loads to permit maximum utilization of the POWERSTAT. Features include a rhodium-plated commutator surface and space-saving core and coil design. Ruggedly constructed for long life and dependable service. Two- and three-gang assemblies are available for increased ratings and three-phase operation.

RATING CHART

INPUT		OUTPUT					
			CONSTANT CURRENT LOAD		CONSTANT IMPEDANCE LOAD		
VOLTS	CYCLES	VOLTS	MAX. AMPS.	MAX. KVA	MAX. AMPS.	MAX. KVA	TYPE
SINGLE PHASE							
120 120	50/60 60	0-120 0-132	1.75 1.75	.21 .23	2.5 1.75	.30 .23	10B
240 240	50/60 60	0-240 0-264	1.75 1.75	.42 .46	2.5 1.75	.60 .46	10B-2
THREE PHASE							
120 120	50/60 60	0-120 0-132	1.75 1.75	.36 .40	2.5 1.75	.52 .40	10B-2
240	60	0-240	1.75	.73	2.5	1.0	10B-3



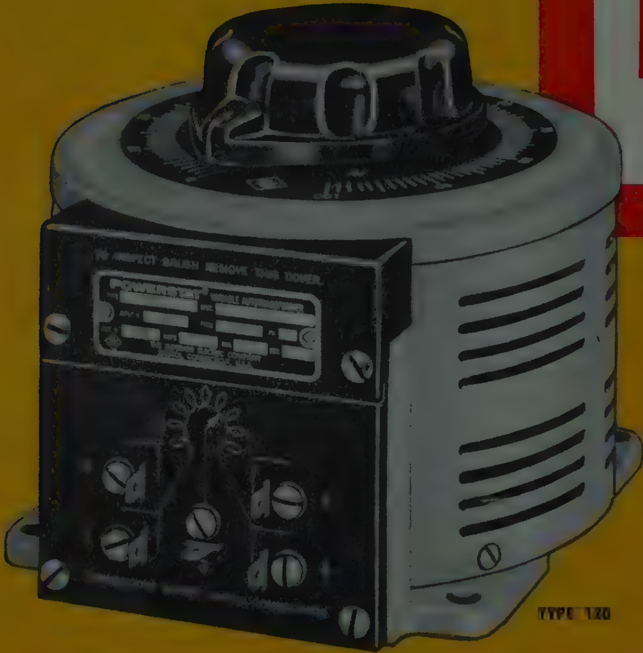
ADAPTER KITS are available for mounting potentiometers, rheostats, tap switches and other devices to operate in unison with POWERSTAT type 10B. If desired, complete assemblies are furnished with the device already mounted.

THE SUPERIOR ELECTRIC COMPANY
Bristol, Connecticut, U.S.A.

SERIES	10B	20	116-216	117-217	126-226	136-236	1156C-1256C	H-[illegible]
AMPERES	1.75	3.0	7.5 3.0	10.0 4.0	12.5/6.0	20.0 9.0	45.0 28.0	20[illegible] and[illegible]

the NEW

126-226 SERIES



TYPE 126

POWERSTAT® variable transformers

For control applications having

. . . up to 12.5 amperes constant-current loads

. . . up to 18.0 amperes constant-impedance loads

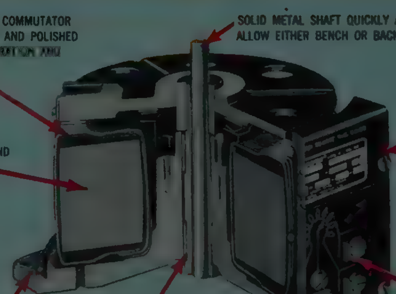
TYPE 3PN126

TYPE 126U

This all-new series rounds out the complete POWERSTAT variable transformer line. The 126-226 series offers open, enclosed, fused, cord-plug and enclosed terminal models; single, two- and three-gang types; manually operated and 5, 15, 30 or 60 second motor-driven assemblies — all available in a new, compact functional design. They incorporate the characteristics inherent in every POWERSTAT: zero wave-form distortion, excellent regulation, high efficiency, conservative ratings, smooth control and linear output voltage.

RATING CHART

INPUT		OUTPUT					
			CONSTANT CURRENT LOAD		CONSTANT IMPEDANCE LOAD		
VOLTS	CYCLES	VOLTS	MAX. AMPS.	MAX. KVA	MAX. AMPS.	MAX. KVA	TYPE
SINGLE PHASE							
120	50/60	0-120	12.5	1.5	18.0	2.2	126
120	50/60	0-140	12.5	1.8	12.5	1.8	
240	50/60	0-240	6.0	1.4	9.0	2.2	226
240	50/60	0-280	6.0	1.7	6.0	1.7	
240	50/60	0-240	12.5	3.0	18.0	4.3	126-2
240	50/60	0-280	12.5	3.5	12.5	3.5	
480	50/60	0-480	6.0	2.9	9.0	4.3	226-2
480	50/60	0-560	6.0	3.4	6.0	3.4	
THREE PHASE							
120	50/60	0-120	12.5	2.6	18.0	3.7	126-2
120	50/60	0-140	12.5	3.0	12.5	3.0	
240	50/60	0-240	6.0	2.5	9.0	3.7	226-2
240	50/60	0-280	6.0	2.9	6.0	2.9	
240	50/60	0-240	12.5	5.2	18.0	7.5	126-3
240	60	0-280	12.5	6.1	12.5	6.1	
480	50/60	0-480	6.0	5.0	9.0	7.5	226-3
480	60	0-560	6.0	5.8	6.0	5.8	



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7.3.2 Gas-Filled Radiation Counter Tubes

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E. Di Anni
E. Wakefield

7.4 Camera Tubes, Phototubes, and Storage Tubes in Which Photo-Emission is Essential

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M. Nowogrodzki
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R. Serrell
L. C. Hobbs
R. L. Snyder
J. R. Johnson
W. H. Ware
C.D.Morrill
J. R. Weiner
W. O. Olander
Way Dong Woo

8.3 Static Storage Elements

W. O. Olander, *Chairman*

T. G. Chen
E. A. Sands
J. Rajchman
R. Stuart-Williams
C. B. Wakeman

8.3.1 Methods of Measurement of Bobbin Cores

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C. Lufcy
E. B. Carne
W. Mitchel
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B. Falk
K. Preston
J. R. Jacquet
M. A. Rosander
R. Kodis
W. C. Seelbach
H. A. Lewis
C. W. Williams
E. M. Ziolkowski

8.4 Definitions (Eastern Division)

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R. P. Mayer
R. A. Kudlich
G. W. Patterson
M. H. Weik

8.5 Definitions (Western Division)

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H. T. Larson
W. S. Speer
W. E. Smith
R. Thorensen
W. H. Ware

8.6 Magnetic Recording for Computing Purposes

S. N. Alexander, *Chairman*

8.8 Analog Computers—Definitions and Symbols

C. D. Morrill, *Chairman*

L. Bauer
W. G. McClintock
S. Fifer
T. A. Rogers
H. Hamer
H. K. Skramstad

8.8.1 Analog Computers—Definitions and Symbols (Western Division)

T. A. Rogers, *Chairman*

G. Bekey
C. Leondes
E. C. DeLand
H. Meissinger
W. K. Kindle
I. Pfeffer

8.9 Digital Computer Logical and Block Diagram Symbols

G. W. Patterson, *Chairman*
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R. J. Nelson
M. P. Marcus
A. J. Neumann
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J. G. Smith (Alternate)

9. Facsimile

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26. Feedback Control Systems

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G. S. Axelby, J. C. Lozier, V. Azgapetian, T. Kemp Maples, L. M. Gould, W. M. Pease, V. B. Haas, Jr., J. E. Ward, R. J. Kochenburger, S. B. Williams, D. P. Lindorff, F. R. Zatlin, D. L. Lippitt, F. Zweig

26.1 Terminology for Feedback Control Systems

G. S. Axelby, *Chairman*

N. H. Choksy, C. F. Rehberg, J. S. Mayo, F. Zweig

26.2 Methods of Measurement and Test of Feedback Control Systems

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R. Gordon, A. F. Stuart, M. Matthews, J. G. Truxal

10. Industrial Electronics

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E. A. Keller, *Vice-Chairman*

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10.1 Definitions

R. J. Roman, *Chairman*

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11. Information Theory and Modulation Systems

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E. R. Kretzmer, *Vice-Chairman*

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11.1 Modulation Systems

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P. L. Bargellini, A. D. Perry, Jr., E. W. Keller, L. S. Schwartz

11.2 East Coast Information Theory

P. L. Bargellini, *Chairman*

11.3 West Coast Information Theory

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C. D. Owens, *Vice-Chairman*

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25.1 Basic Standards and Calibration Methods

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25.2 Dielectric Measurements

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25.3 Magnetic Measurements

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25.6 High Frequency Measurements

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25.10 Oscillography

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29. Medical Electronics

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29.1 Nomenclature

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29.2 Methods of Measurement

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16. Mobile Communication Systems

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12. Navigation Aids

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13. Nuclear Techniques

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14. Piezoelectric and Ferroelectric Crystals

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14.1 Ferroelectric Crystals

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14.2 Piezoelectric Crystals

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14.4 Definitions for Magnetostriction

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14.5 Piezoelectric Ceramics

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27.1 Basic Measurements

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27.2 Definitions

27.3 Radio and TV Receivers

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27.4 Radio Transmitters

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27.5 Industrial Electronics

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27.7 Mobile Communications Equipment

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27.12 Navigational and Communication Equipment

17. Radio Receivers

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17.10 Automatic Frequency and Phase Control

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17.11 AM-FM Broadcast Receivers

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15. Radio Transmitters

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15.1 FM Transmitters

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15.2 Radio-Telegraph Transmitters up to 50 MC

I. R. Weir, *Chairman*

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15.3 Double Sideband AM Transmitters

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15.4 Pulse-Modulated Transmitters

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15.5 Single Sideband Radio Communication Transmitters

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15.6 Television Broadcast Transmitters

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19. Recording and Reproducing

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F. A. Comerci, *Vice-Chairman*

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19.1 Magnetic Recording

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19.2 Mechanical Recording

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19.3 Optical Recording

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19.5 Flutter

F. A. Comerci, *Chairman*

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28. Solid State Devices

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V. P. Mathis, *Secretary*

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28.0.1 General Definitions

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28.0.2 Cryogenic Devices

A. E. Slade, *Chairman*

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28.4 Semi-Conductor Devices

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A. C. Sheckler, *Chairman* (AIEE)

G. Abraham, R. P. Lyon, J. B. Angell, R. Morrison, E. N. Clarke, C. W. Mueller, A. Coblenz, M. B. Prince, S. K. Ghandhi, R. L. Pritchard, J. M. Goldey, B. J. Rothlein, B. Jacobs, H. N. Sachar, J. D. Johnson, A. P. Stern, C. H. Knowles, R. L. Trent, R. Ure

28.4.2 Methods of Test for Transistors for Linear CW Transmission Service

A. Coblenz, *Chairman*

28.4.3 Definitions and Letter Symbols of Semiconductors

B. J. Rothlein, *Chairman*

28.4.4 Methods of Test for Semiconductor Devices for Large-Signal Applications

R. L. Trent, *Chairman*

A. W. Berger, R. S. Hill, F. H. Blecher, C. Huang, R. M. LeLacheur

28.4.5 Methods of Test for Bulk Semiconductors

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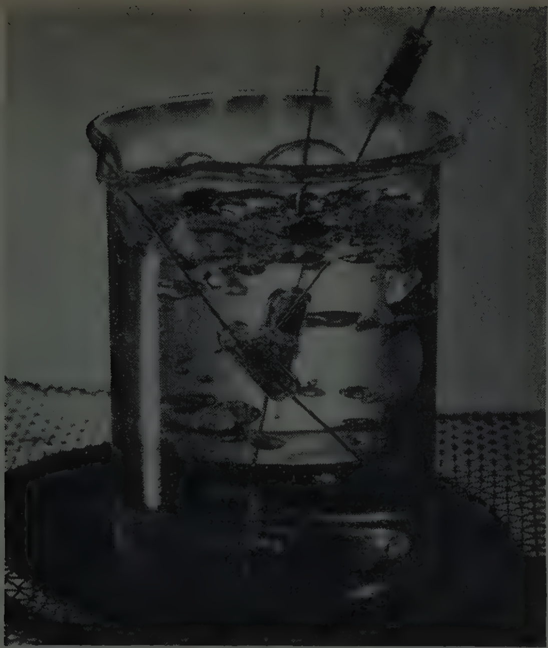
G. Bemski, A. Kestenbaum, D. C. Cronemeyer, M. F. Lamorte, I. Drukaroff, J. Mandelkorn, D. T. Stevenson



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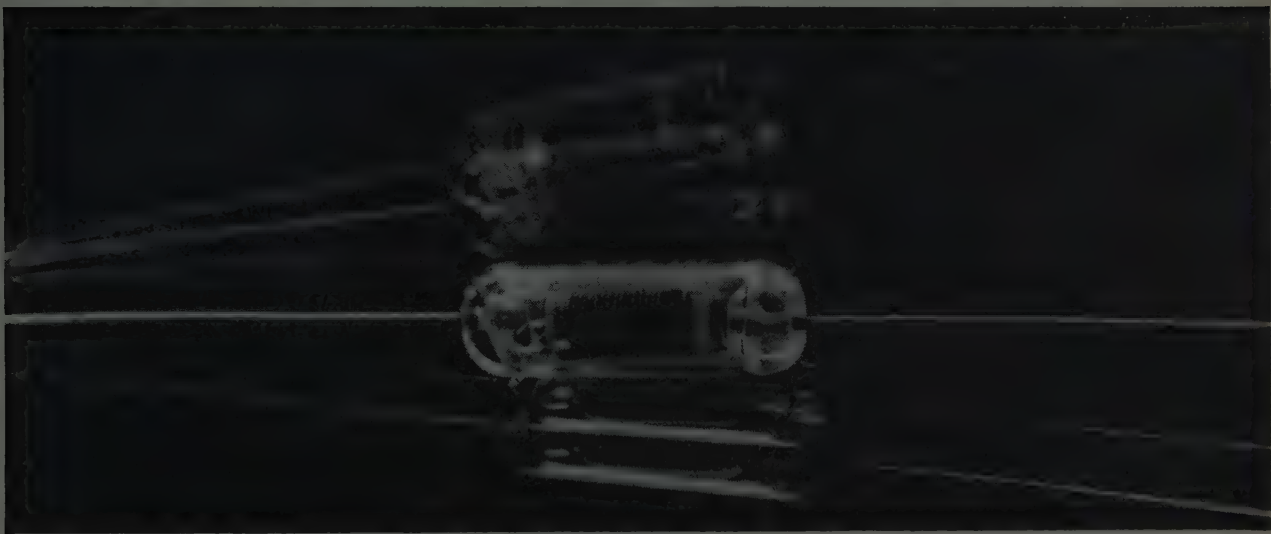

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R. Christensen
I. A. Lesk
J. Defandorf
A. Nash
D. E. Sawyer

28.4.7 TRANSISTOR INTERNAL PARAMETERS

R. L. Pritchard, *Chairman*

R. B. Adler
J. M. Early
J. B. Angell
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28.4.8 SEMICONDUCTOR DEVICES SYMBOLS

S. K. Ghandi, *Chairman*

B. J. Rothlein

28.4.9 SEMICONDUCTOR DIODE DEFINITIONS

C. H. Knowles, *Chairman*

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R. P. Lyon
D. C. Dickson
R. H. Rediker
B. Jacobs
A. C. Sheckler
J. D. Johnson
J. R. Thurrell

28.4.10 SEMICONDUCTOR DIODE MEASUREMENTS

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A. Bakanowski
R. Doyle
D. R. Fewer
J. Fishel
J. H. Forster (alternate)
J. Gillette
C. Irwin (alternate)
E. F. Platz
A. C. Sheckler

28.4.12 DEFINITIONS AND METHODS OF TEST FOR *P-N-P-N* DEVICES

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F. Burns
A. Kaminski
R. Biesele
W. T. Matzen
N. Holonyak, Jr.
H. N. Starke
F. S. Stein

28.4.13 HIGH FREQUENCY DIODES

E. N. Clarke, *Chairman*

A. Bakanowski
S. Karandanis
R. A. Campbell
W. G. Matthei
E. Feldman
S. Mayburg
K. C. C. Gunn
C. Messenger
N. Houlding
E. L. Steele
A. Uhlir, Jr.

28.5 DIELECTRIC DEVICES

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F. A. Schwertz, *Co-Chairman* (AIEE)

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R. E. Benn
E. F. Mayer
W. Bixby
C. F. Pulvari
J. Bramley
J. R. Roeder
H. Diamond
C. A. Rosen
H. Epstein
E. A. Sack
W. Gardner
R. M. Schaffert
R. B. Gray
C. F. Spitzer
R. E. Halsted
P. N. Wolfe

28.5.1 NON-LINEAR DIELECTRIC DEFINITIONS

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H. Diamond
C. F. Pulvari
R. A. Fotland
N. Rudnick
N. R. Kornfield
E. A. Sack
E. E. Loebner
C. F. Spitzer
S. W. Tenon

28.5.2 DIELECTRIC ELECTRO-OPTIC DEFINITIONS

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E. E. Loebner
F. Gordon
R. Rulon
M. S. Hall
E. A. Sack
H. L. Ivey
F. A. Schwertz
C. F. Spitzer

28.5.3 DEFINITIONS, FORMATION AND UTILIZATION OF ELECTROSTATIC IMAGES

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R. E. Benn
J. S. Rydz
W. Bixby
F. A. Schwertz
H. Epstein
O. Ulrich
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L. E. Walkup

28.7 MASERS AND VARIABLE REACTANCE TRANSDUCERS

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A. D. Berk
J. W. Meyer
E. N. Clarke
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P. H. Vartanian, Jr.
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28.8 THERMOELECTRIC DEVICES

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F. Anders
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I. Cadoff
P. Klein
F. Donahoe
E. H. Lougher
R. W. Fritts
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N. Fuschillo
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21. SYMBOLS

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C. D. Mitchell
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R. V. Rice
D. Drusdow
M. P. Robinson
W. A. Ford
R. M. Stern
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21.3 FUNCTIONAL SYMBOLS FOR SWITCHING AND CONTROL EQUIPMENT

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V. C. Christensen
J. J. Lamb
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W. J. Everts
J. S. Osborne
H. F. Herbig
T. J. Reilly
T. H. Jeffery
W. J. Wichtendahl

21.5 NEW PROPOSALS AND SPECIAL ASSIGNMENTS

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21.7 LETTER SYMBOLS

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P. R. Clement
D. M. Howell
J. F. Craib
D. E. Mode
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J. A. Raper
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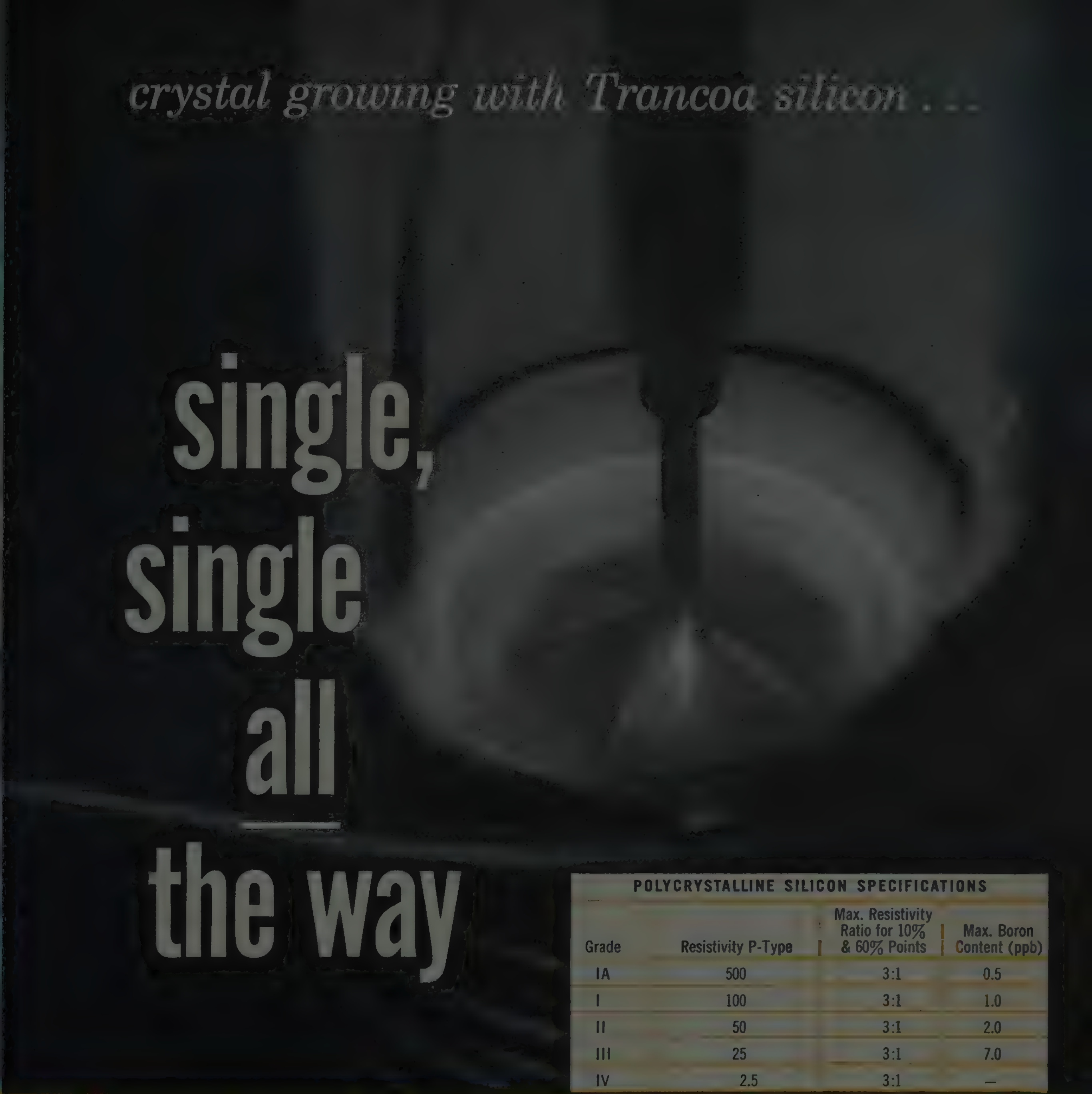

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IN536	50	35	50	750	500	250	15	–65 to +165	–65 to +175	1.1 at 500 ma	5	400
IN537	100	70	100	750	500	250	15	–65 to +165	–65 to +175	1.1 at 500 ma	5	400
IN538	200	140	200	750	500	250	15	–65 to +165	–65 to +175	1.1 at 500 ma	5	300
IN539	300	210	300	750	500	250	15	–65 to +165	–65 to +175	1.1 at 500 ma	5	300
IN540	400	280	400	750	500	250	15	–65 to +165	–65 to +175	1.2 at 500 ma	5	300
IN1095	500	350	500	750	500	250	15	–65 to +165	–65 to +175	1.2 at 500 ma	5	350
IN547	600	420	600	750	500	250	15	–65 to +165	–65 to +175	1.2 at 500 ma	5	350

6 Types for MAGNETIC-AMPLIFIER applications requiring exceptionally low-leakage currents

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IN440-B	100	70	100	750	500	250	15	165	–65 to +175	1.5 at 750 ma	0.3	100
IN441-B	200	140	200	750	500	250	15	165	–65 to +175	1.5 at 750 ma	0.75	100
IN442-B	300	210	300	750	500	250	15	165	–65 to +175	1.5 at 750 ma	1.0	200
IN443-B	400	280	400	750	500	250	15	165	–65 to +175	1.5 at 750 ma	1.5	200
IN444-B	500	350	500	650	425	0	15	150	–65 to +175	1.5 at 750 ma	1.75	200
IN445-B	600	420	600	650	400	0	15	150	–65 to +175	1.5 at 750 ma	2.0	200

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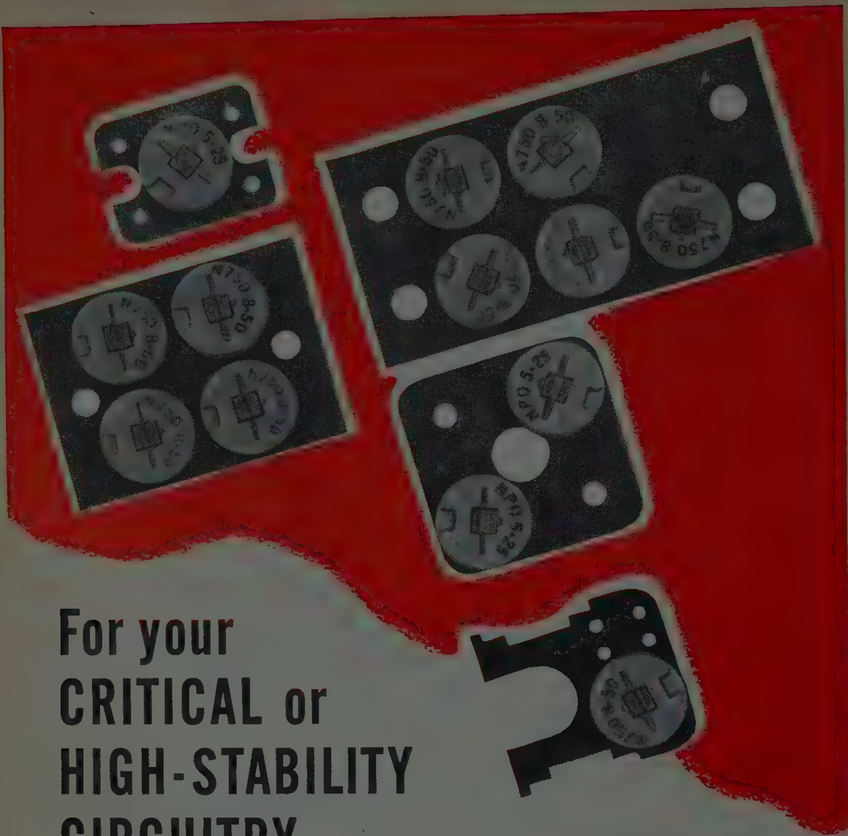

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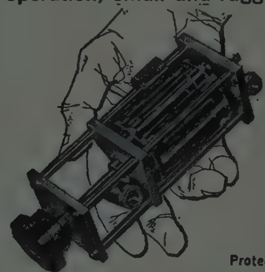

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ATTENUATOR PADS

Available in any conceivable combination of male and female Type C and Type N connectors. Maximum length of 3" for any attenuation value.
GENERAL SPECIFICATIONS
VSWR: Less than 1.2 to 3000 mc.
Characteristic Impedance: 50 ohms.
Attenuation Value: Any value from 0 db to 60 db including fractional values.
Accuracy: ±0.5 db; values above 50 db have rated accuracy of attenuation through 1000 mc only.
Power Rating: 1.0 watt sine wave.

COAXIAL TERMINATIONS

Small-stable-50 or 70 ohms

½-Watt: 50 ohms impedance, TNC or BNC connectors, dc to 1000 mc, VSWR less than 1.2.

1-Watt: 50 ohms impedance, dc to 3000 mc or dc to 7000 mc, Type N or Type C connectors, male or female; VSWR less than 1.2, 70 ohm, Type N, male or female terminations available.

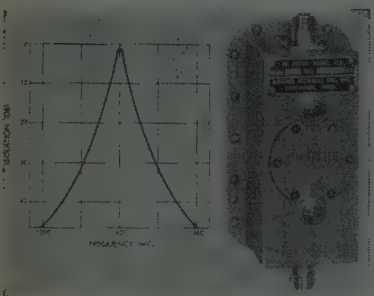
Fast delivery on all items.
Send for complete literature.

STODDART
AIRCRAFT RADIO CO., INC.
6644 Santa Monica Blvd., Hollywood 38, Calif.
HOllywood 4-9292

NEWS
New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

Midget Cavity Filter



Adams-Russell Co., Inc., 200 Sixth St., Cambridge, Mass., announces the introduction of their new midget cavity filter, Model 410, available for any frequency in the 400–2,000 mc range. This rugged dual cavity is tunable over a limited range of from 3 to 10% depending on center frequency. It is airtight and will withstand shock, vibration, and temperature extremes. Response curve and bandwidth are essentially the same for any pass frequency. Other features include: Power 20–50 watts, according to pass frequency; Insertion Loss, 1 db; 3 db Bandwidth, 8 mc; 30 db Bandwidth, 60 mc; Size, $3\times3\times5\frac{1}{2}$ inches; Weight, 28 ounces.

For complete information on the filter, write to the firm.

Pulse and Pip Generator

The **Kay Electric Co.,** Dept. PI, 14 Maple Ave., Pine Brook, N. J., announces the introduction of the Vari-Marker, a combined pulse and birdie-pip marker generator designed for specific use with their high level sweeping oscillator, the Vari-Sweep. When the swept RF output of the Vari-Sweep is fed into the Vari-Marker, a birdie-pip, continuously variable from 1.6 to 442 mc, is generated and is available at separate output terminals. A high-level AGC'd CW signal, covering the same frequency range, is also available. In addition, any one of up to ten groups of three positive, pulse-type, crystal-controlled markers may be selected, available at the same terminals as the birdie-pip marker.

The markers generated by the Vari-Marker may be fed directly into the vertical amplifier of an oscilloscope and used to frequency-calibrate the circuit under test and to readily identify any specific frequencies of interest.

Specifications for the Kay Vari-Marker are: Frequency Range: Birdie-Pip: Continuously variable from 1.6 to 442 mc in eight, switched overlapping bands; direct-reading frequency dial calibrated to within ±1.0%. Pip: Ten position switch allows selection of up to 30 pulse-type, crystal-controlled markers at customer-specified frequencies, placed three to a band, anywhere between 1.6 and 442 mc.

Marker Amplitude: Continuously variable, zero to approximately 5.0 volts peak. Variable CW, 1.0 volt rms into nominal 70 ohms (50 ohms upon request), AGC'd for flatness of ±0.5 db over the band with switched attenuation steps of 20, 20, 10, 6 and 3 db.

Power Supply: Input approx. 180 watts, 117-V (±10%), 50–60 cps ac. B+ electronically regulated.

Dimensions: $19\frac{1}{2}\times13\times9$ inches. Weight: 35 pounds.

Greene President of Heath Co.

Allan W. Greene has been appointed president of the **Heath Co.,** Benton Harbor, Mich., it was announced here today by Thomas Roy Jones, president, Daystrom, Inc.

The Heath Co., with its **Heathkit** products, is the world's largest manufacturer of electronic equipment in kit form. It is one of ten operating divisions of Daystrom, Inc., a leading electrical and electronics manufacturer.

Prior to his present appointment, Greene was general manager of Moto-Mower, Inc., Richmond, Indiana, and a vice president of Detroit Harvester Co., of which Moto-Mower, Inc., is a subsidiary.

Greene, a native of Clinton, Wis., was graduated from the University of Wisconsin in 1941. He started his business career as a college trainee with Sears Roebuck and Co.; later joined the Packard Motor Car Co.; and then became service manager and manager of sales training of the Reo Co., now a division of the Motor Wheel Corp.

Medium Power Low-Cost Transistor

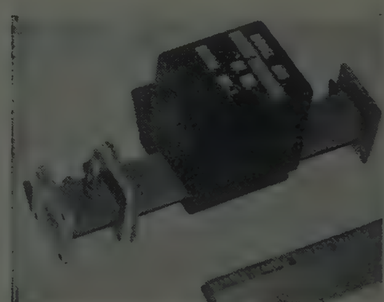
Bendix Aviation Corp., Red Bank Div., Semiconductor Dept., Long Branch, N. J., announces a new medium-power transistor series for applications in single-ended Class B drivers, output amplifiers for portable radios and TV, and other commercial units.

The transistor, called Yeoman and designated the 2N1176, A and B series, features lower cost per unit than similar transistors, according to Dr. Robert R. Meijer, marketing manager.

It has a low saturation voltage of 0.3 vdc, and can be supplied in 15, 40, and 60 voltage ratings with a 300 ma dc maximum collector current rating. Its linear current gain characteristics permit efficient switching and low distortion output.

Power For TR Switch Tube

A series of "Mini-Keep" power supplies offering a packaged source of power for microwave T-R switch tubes is now available from **Burmac Electronics Co., Inc.,** 142 S. Long Beach Rd., Rockville Centre, L. I., N. Y. Designed for use in radar systems, laboratories and production test installations, Mini-Keep supplies can be mounted to a chassis, bulkhead or waveguide section adjacent to the T-R tube assembly.



The output impedance is sufficiently low to permit use of any required series resistor called for under T-R tube specifications. One of the units in the line is Model No. K-800. Its specifications include an output voltage of −1000 vdc, output current of 200 microamperes and ripple of 5% peak to peak. The input is stated as 115 volts, RMS at 60 or 400 cps. Its total volume is approximately 8 cubic inches, and the price is $39.50.

(Continued on page 148A)

Creative Microwave Technology

Published by MICROWAVE AND POWER TUBE DIVISION, RAYTHEON COMPANY, WALTHAM 54, MASS., Vol. 1, No. 5

NEW RAYTHEON MICROWAVE TUBE DEVELOPMENTS

Miniature pulsed magnetrons for missile beacon applications are ruggedly constructed with integral magnets. The RK-7461 is tunable from 9,300 to 9,500 mc and has minimum peak power output of 60 watts. It is 1¼" in diameter and 2½" long, and weighs only 6 ounces.

RK-7461 QK-735

The QK-735 is tunable from 5,400 to 5,900 mc with minimum peak power output of 400 watts. 1½" in diameter and 3¼" long, it weighs 8 ounces.

* * *

Designed for electronic countermeasures and FM/CW operations, the QK-625 BWO provides a minimum CW power output of 180 watts and a nominal CW power output of 250 to 350 watts over the 2,500 to 3,000 mc band. The tube is voltage tunable over the entire range with tuning sensitivity of approximately 0.4 mc/volt. Liquid-cooled, the QK-625 BWO is equipped with an integral

permanent magnet, and can be mounted in any position.

* * *

Small-signal gain of up to 35 db in microwave relay links is achieved by means of a new compact traveling wave tube amplifier -- the QK-542. This permanent-magnet focused CW tube has nominal saturated power output of 5 watts over 5,900 to 7,400 mc. An integral UG 344/U waveguide-type flange is supplied as standard. With an optional coaxial output coupler the QK-542 covers 4,000 to 8,000 mc.

Ideal for linear accelerators and high-power radar systems. The QK-783 and QK-622 Amplitrons operate over the 2,700-2,900 mc and 2,900-3,100 mc bands, respectively, at a peak power of 3 megawatts and a typical efficiency of 75%. Because no heater is required, these tubes are capable of exceptionally long life. RF gain is 8 db under rated conditions, and as high as 12 db at lower peak power outputs. Phase pushing figure is less than 0.5 degrees for a 1% variation of anode current.

* * *

Compiled as a Raytheon service to the field, new Consolidated Data Booklet contains comprehensive information about principal unclassified magnetrons, klystrons, backward wave oscillators and special purpose tubes manufactured by Raytheon. Characteristics presented include maximum ratings, typical operating values, band or frequency ranges and other essential data for microwave engineers and purchasing departments.

BROAD

with these convenient, precision

NEW AMPLIFIER!

Just clamp on probe and read current instantly!

hp 154A Voltage/Current Dual Channel Amplifier

SPECIFICATIONS

(When plugged into -hp- 150A/AR Oscilloscope)

CURRENT CHANNEL	
Band Pass:	50 cps to 8 MC.
Sensitivity:	10 calibrated ranges, 1 to 1,000 ma/cm, 1, 2, 5, 10 sequence. Accuracy ± 5%. Vernier between steps (extends 1,000 ma/cm range to at least 2,500 ma/cm).
Max ac Current:	10 amperes rms 20 KC and above. Below 20 KC core saturation reduces current capability proportional to frequency.
Max dc Current:	Direct current to ½ amp has no appreciable effect.
Input Impedance:	Approx. 0.01 ohm shunted by 0.8 uh.
VOLTAGE CHANNEL	
Band Pass:	dc coupled: dc to 10 MC, 0.035 μsec rise time. ac coupled: 2 cps to 10 MC, 0.035 μsec rise time.
Sensitivity:	9 calibrated ranges, 0.05 to 20 v/cm; 1, 2, 5, 10 sequence. Accuracy ± 5%. Vernier between steps.
Input Impedance:	1 megohm (nominal), 30 uuf shunt.
GENERAL	
Vertical Presentation:	(1) Either voltage or current signal continuously or (2) voltage and current signals sampled at 100 KC or on alternate traces.
Vertical Position:	Each channel individually adjustable.
Price:	$430.00 (includes current probe).

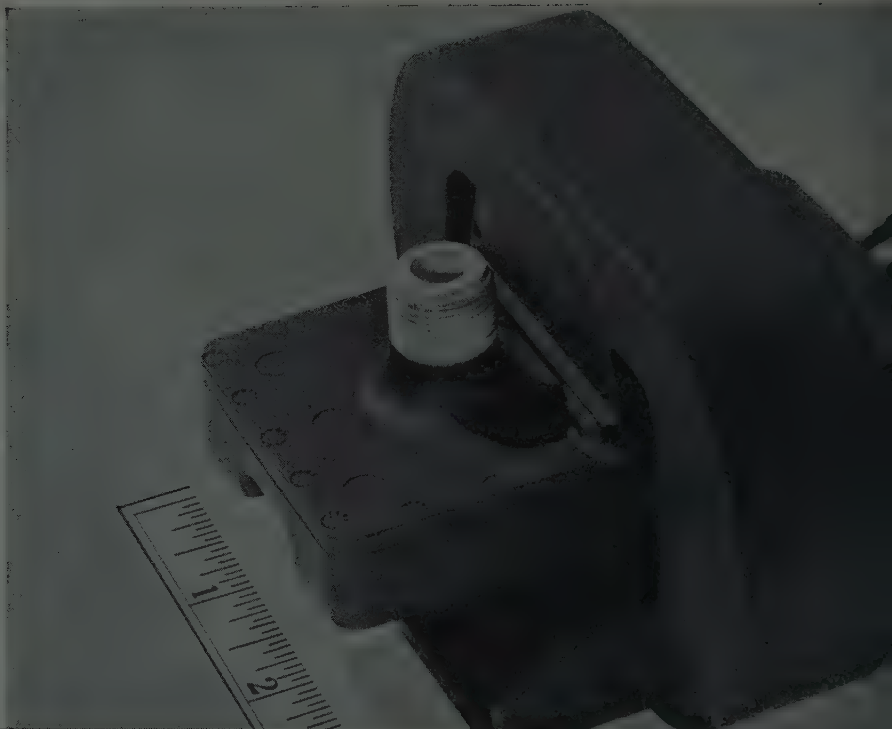
The new hp 154A's exclusive "clamp-around" probe permits fast, direct measurement of current from 50 cps to 8 MC, 1 ma to 15 amperes (peak-to-peak) *without breaking into the circuit, loading, or voltage drop due to resistor insertion.* Here is a time-saving convenience feature of real significance in the investigation of transistors, logic circuits and other measurements where current information is of prime importance.

In addition, the 154A — actually two instruments in one—makes possible swift, simple and direct comparison between voltage and current waveforms. In this comparison service, one section of the 154A reads current while the other reads voltage in a manner identical with other hp voltage indicating instruments. Comparison is achieved by electronic channel switching—through alternate sweeps or 100 KC chopping. Either of the 154A's dual channels may also be used individually.

hp now offers better-than-ever service

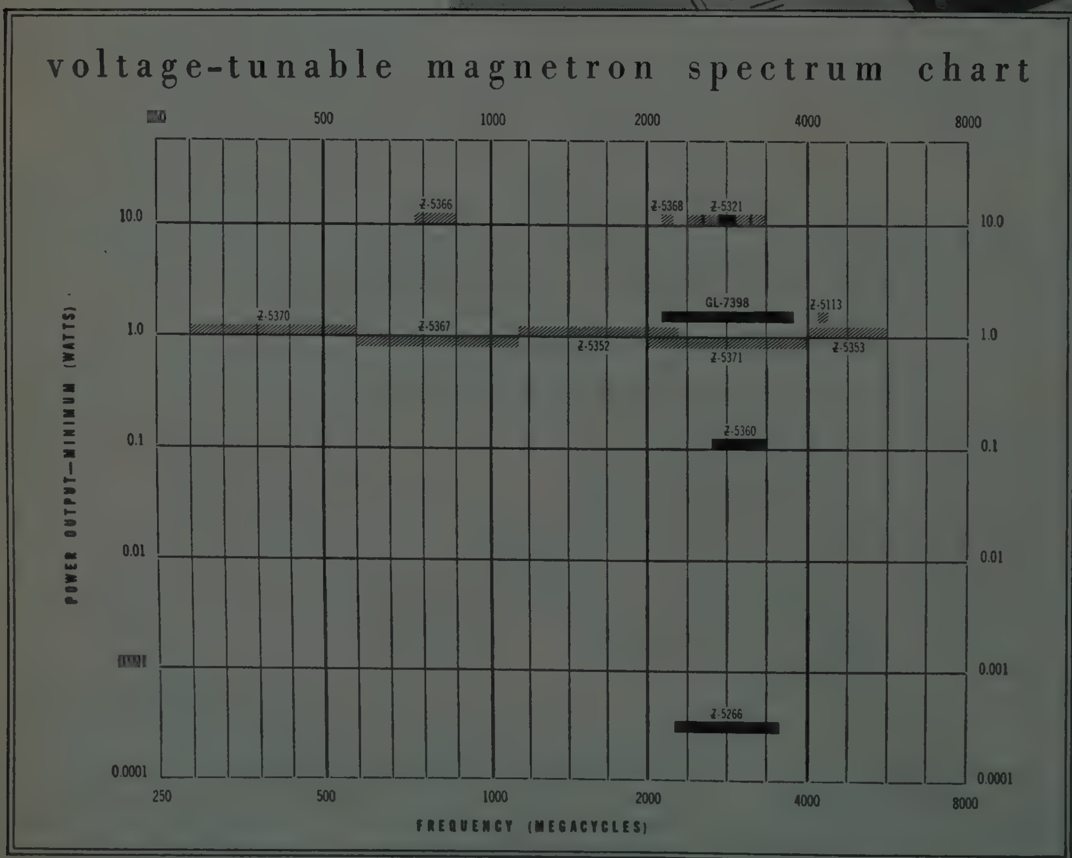
GENERAL ELECTRIC GL-7398*
VOLUME PRODUCTION, AVAILABLE

**formerly designated Z-5300*

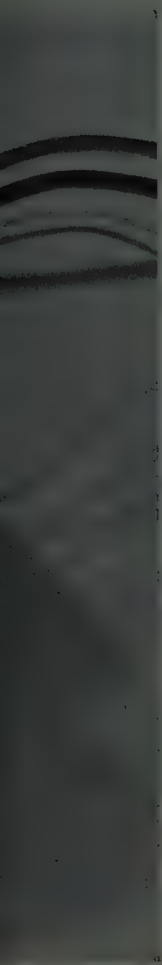


Voltage-tunable magnetrons now available are indicated by solid areas. Other developments are shown by cross-hatched areas.

▼



VOLTAGE-TUNABLE MAGNETRON IN FOR IMMEDIATE DELIVERY!



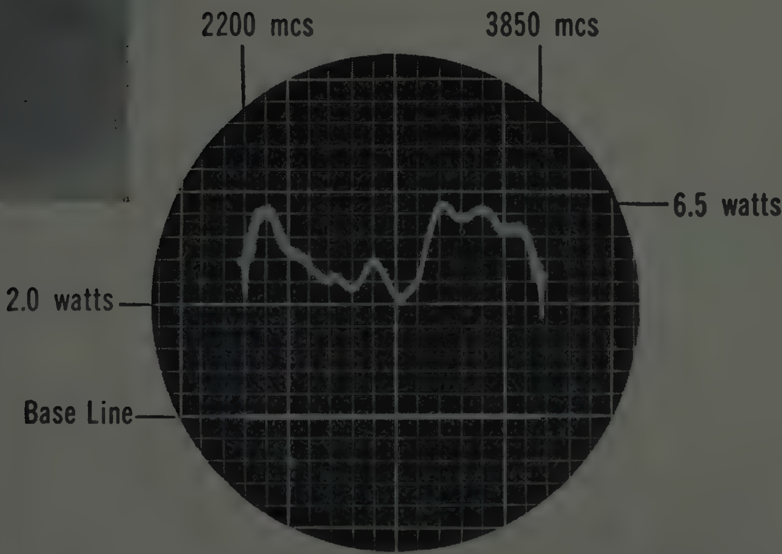
The General Electric GL-7398 voltage-tunable magnetron, a complete RF power source ideal for FM modulation, is now in volume production and available for immediate delivery. Moreover, samples are currently available or can be developed by use of proved technology to meet any need within the frequencies charted on the opposite page. The GL-7398 is designed for use in many applications, such as:

- FM telemetering or video transmission
- Beacon transmitters
- Local oscillators in electronically tunable radars
- Drivers in pulse-to-pulse frequency-shift radars
- FM altimeters
- Broad-band signal generators
- Countermeasure transmitters
- Drivers for countermeasure amplifiers

Output frequency can be varied linearly over a range of nearly 2 to 1 by sweeping the anode voltage. Power output is relatively flat at a minimum of 2 watts. The GL-7398 is a rugged, compact, packaged unit with these characteristics:

Anode voltage at 3 kmc	— 1250 volts
Anode current	— 10-20 ma
Frequency range	— 2200-3850 mcs
Tuning rate	— approx. 3 mcs/volt
FM rate	— 10 mcs or higher
Weight	— 3.1 lbs.

By use of internal narrow-band circuits, a variation (Z-5321) is available which gives a minimum of 10 watts power over a 200 mc bandwidth at a factory-predetermined centerpoint in the 2 to 4 kmc band. Other variations with built-in attenuators for local oscillator applications can be supplied (Z-5360 and Z-5266). *Power Tube Department, General Electric Company, Schenectady, New York.*



◀ Typical power—frequency of the GL-7398 shows power constant over the full band to within plus-or-minus 3 db.

Progress Is Our Most Important Product

GENERAL ELECTRIC

IRE People

Isaac L. Auerbach (S'46–M'49–SM'52–F'58), president of Auerbach Electronics Corporation, Narberth, Pa., was recently awarded the grand medal of the city of Paris for his work in organizing the first International Conference on Information Processing and for his contributions to the field. This conclave, held in Paris June 13–23, saw the meeting of the world's leading scientists and engineers in the field of computers and information processing.

I. L. Auerbach

Mr. Auerbach, a pioneer in the information processing field, was chairman of the United States Committee, sponsored by UNESCO, which was instrumental in organizing this international assembly. He also served as chairman of a session of the conference titled "Computer Techniques of the Future."

He formed Auerbach Electronics Corporation in Narberth two years ago. His firm specializes in systems engineering and electronic equipment development projects for industrial and military clients. He was formerly manager of the Special Products Division of the Burroughs Corporation Research Center in Paoli, Pa., where he directed many large-scale defense projects, including the AN/FST-2 SAGE Data Processor and the ATLAS Guidance Computer.

He received the B.S. degree in Electrical Engineering from the Drexel Institute of Technology in 1943 and the M.S. degree in Applied Physics from Harvard University in 1947. He was one of the leaders in applying magnetic cores and transistors to digital data processing. He designed and developed the static magnetic memory system for the ENIAC computer, and directed the development of the first application of magnetic cores to numerical machine tool control and other automation equipments. He demonstrated the first digital mercury delay line system for the BINAC and UNIVAC computers, and developed standard unitized packaging systems for these and other systems.

❖

G. Dale Bagley (SM'53) has been named director of the Telecommunications Lab. of the Research and Development Div., Space Technology Labs., Inc. He is a member of the firm's senior staff.

Dr. Bagley earned the B.S. and M.S. degrees in physics from the University of Utah and the Ph.D. from the University of California, Berkeley. He has worked for 23 years on radar systems, missile guidance systems and navigation systems; nine of these years were spent at the Headquarters Signal Corps Engineering Laboratories, Ft. Monmouth, N. J.

A Thompson scholar at the University of California, he is a member of Sigma Xi.

❖

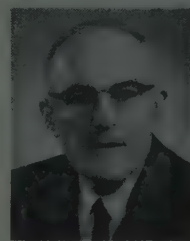
Melvin A. Breuer (S'58), a 1959 graduate of U.C.L.A., recently joined the technical staff of the Ramo-Wooldridge Division of Thompson Ramo Wooldridge Inc.

A native of Los Angeles, he majored in engineering at U.C.L.A. where he functioned as a senior engineering aide during his undergraduate days.

He is a member of Sigma Xi and Tau Beta Pi, honorary societies. During his studies at U.C.L.A. Breuer received a faculty citation, a Northrop Fellowship and a Telemeter Research Grant.

❖

Robert S. Burnap (A'30–F'47), pioneer electron tube engineer, retired as Manager, Commercial Engineering, RCA Electron Tube Division, upon attainment of retirement age. He will continue to serve the Division as a consultant. He has been associated with RCA and predecessor companies for forty-two years.



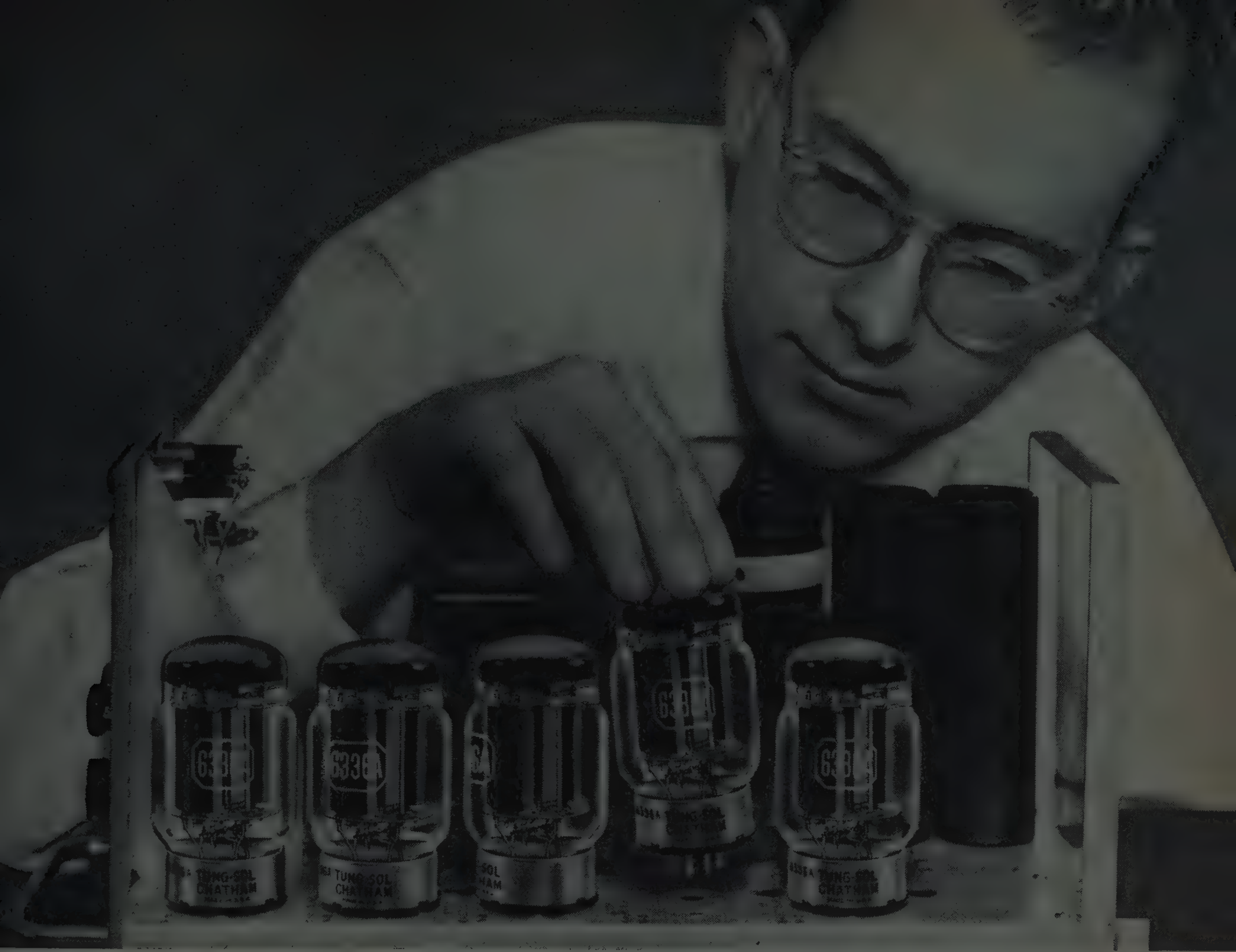
R. S. Burnap

Born in Monterey, Mass., Mr. Burnap received the B.S. degree from Massachusetts Institute of Technology. He remained at M.I.T. for one year as a research assistant in Illumination and Photometry. In 1917 he started his career as an engineer with the Edison Lamp Works of the General Electric Company at Harrison and was placed in charge of the Physical Laboratory. During World War I, he was a master signal electrician with the Testing Section, Research Laboratory of the Signal Corps. He returned to the Edison Lamp Works after his military service and was engaged in engineering and lamp design. He advanced to the position of Manager of the Commercial Engineering Section of the Lamp Works in 1924. When the Harrison plant was acquired from G.E., he transferred to RCA in the same position. He has been Manager, Commercial Engineering, since 1930.

Mr. Burnap holds several patents on lamp design and has been active on many professional society and industry standardization committees. He was elected a Fellow of the Society of Motion Picture and Television Engineers in 1934, and of the American Institute of Electrical Engineers in 1951.

❖

(Continued on page 56A)



Engineer A. M. Darbie installs a Tung-Sol/Chatham 6336A twin power triode in a Harrison Labs 2B regulator, part of a 200B high current power supply. Superior power handling ability of the 6336A lets Harrison Labs offer the regulator with a 5-tube complement in addition to a 7-tube model.

Harrison Labs HLAB gains flexibility with Tung-Sol/Chatham 6336A!

Harrison Laboratories, quality manufacturer of Berkeley Heights, N. J., offers designers its 2B regulator with a 5 or 7-tube complement. Superior power handling ability of Tung-Sol/Chatham's 6336A twin power triode makes possible the 5-tube version that features operation over a wider line voltage variation without change of transformer taps.

Over more than a year, Tung-Sol/Chatham's 6336A has performed with exceptional reliability. Users of Harrison Labs 2B regulator especially appreciate the reduced downtime and maintenance stemming from 6336A's long life and electrical stability. In all, Harrison Labs evaluates the Tung-Sol/Chatham 6336A a wise design choice.

Harrison Labs adds another name to the growing list of manufacturers benefitting from the reliable efficiency of Tung-Sol tubes and semiconductors. So can you. Tung-Sol makes a quality unit for virtually every industrial and military need. Our applications engineers will gladly assess your circuitry and help discover how you can profit by specifying Tung-Sol. Tung-Sol Electric Inc., Newark 4, New Jersey. TWX: NK193

ts TUNG-SOL®

IRE People

(Continued from page 54A)

Robert E. Davis (S'42–A'44–M'47) has been selected to take over a newly created position of Engineering Manager at Rixon Electronics. Prior to joining Rixon, he was affiliated with Litton Industries of Maryland, College Park, Md. His most recent position at Litton was Engineering Manager in charge of design and production of automatic jamming systems. Before that, he was Manager of the company's Missile Instrumentation Section where he supervised work on telemetry systems and components, (specifically, Redstone and Jupiter Nose Cone Telemetry Systems), design of stainless cable vibration isolation systems, and probe tests on missile fuzing systems. While at Maryland Electronics Manufacturing Corp. from 1956–1957 (the company merged with Litton Industries in 1957) he started out as Project Engineer working on circuit design of Automatic Electronic Position Indicator Systems. Later he became Manager of the Missile Instrumentation Section, the position in which he continued when MEMCO first merged with Litton.

R. E. Davis

From 1952–1956, he was affiliated with the ERCO Division of ACF Industries, Inc. where he was first Assistant Project Engineer and later promoted to Development Engineer. At ACF, he directed work on improved missile fuzing systems and helped design simulation circuits for sonar, sonobuoy, and radio aid systems. While with the television station WTTG, A. B. Dumont Laboratories, he was technical supervisor and also video operator in charge of operation, installation, and maintenance of remote studio and projection image orthicon and iconoscope camera equipment. He also worked with UHF and VHF FM-and-AM Transmitting equipment. Prior to his affiliation with WTTG, Davis spent five years at the Naval Research Laboratory where he worked on radar, electronic countermeasures, and captured enemy equipment.

Mr. Davis is a native of Oklahoma City, Oklahoma and attended the University of Oklahoma where he received the B.S. degree in electrical engineering in July, 1942. He is a member of the AIEE.

❖

Robert W. Carr (S'55–M'58) has been named manager of the microphone development department of Shure Brothers, Inc., Evanston, Ill. He joined Shure in 1948 and has been a senior engineer in microphone development.

He is a member of the Acoustical Society of America, and the Chicago Acoustical and Audio Group.

❖

(Continued on page 58A)

IRE People

(Continued from page 56A)

Microtran Co. of Valley Stream, N. Y., announces the appointment of **Richard Chaber** (S'47–A'48–M'55) as Vice-President in charge of Engineering.

R. CHABER

Formerly Chief Engineer of the company, Mr. Chaber joined Microtran in 1953. Prior to this, he was employed by United Transformer Co. and Freed Transformer Co. He received the Bachelor of Electrical Engineering degree at the School of Technology, College of the City of New York, N. Y.

❖

Capt. Gilbert L. Countryman, USN, Ret. (SM'56), who held the top electronics post in the U. S. Navy as Assistant Chief of the Bureau of Ships for Electronics, has joined Page Communications Engineers, Inc.

G. L. COUNTRYMAN

As Assistant Chief for the Bureau of Ships from 1956–58, he was responsible for the Navy's electronics program on land and sea. Prior to his retirement last month, Capt. Countryman was Industrial Engineering Officer for the Charleston Naval Shipyard.

During World War II he served on Admiral Nimitz's staff as Assistant Fleet Radio Officer, CINCPAC and CINCPOA. With the Navy for 24 years, Capt. Countryman was also Director, Electronics Logistics, Bureau of Ships and Comptroller of the U. S. Navy Shipyard Charleston, S. C.

At Page he will assume management responsibilities associated with the firm's world-wide operations.

❖

Jerry R. Estes (M'59), electrical engineer, has joined the Engineering division of Ramo-Wooldridge, a division of Thompson Ramo Wooldridge Inc. He was formerly engaged in microwave component design for an advanced radar system at the Johns Hopkins Applied Physics Laboratory.

He is a native of Denver, Colo., and received the B.S. degree in 1958 from the University of Colorado. He is a member of Eta Kappa Nu and Sigma Tau honorary societies, and an Associate Member of the American Institute of Electrical Engineers.

❖

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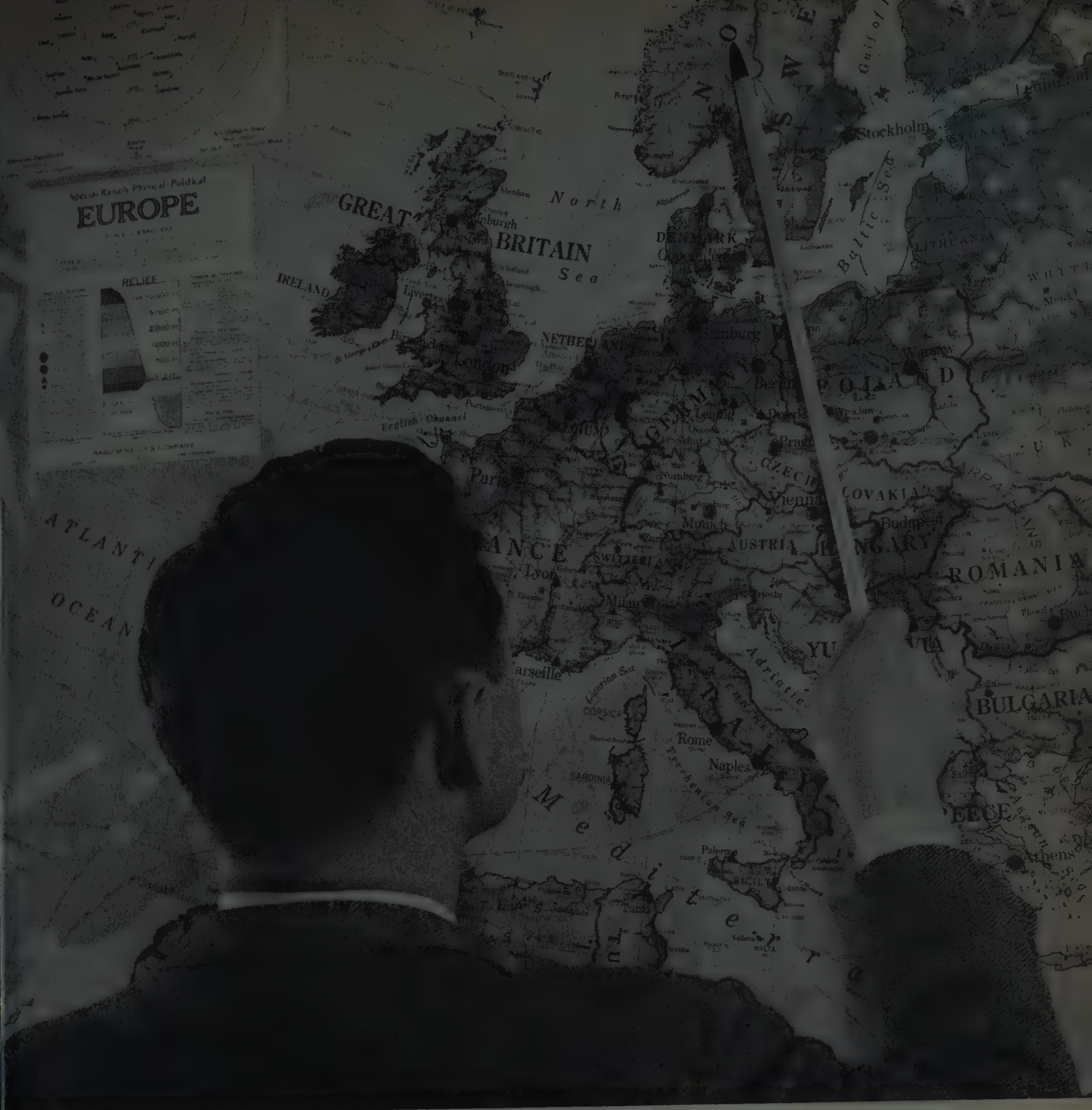
EUROPE
RELIEF
GREAT BRITAIN
North Sea
IRELAND
Stockholm
Baltic Sea
DENMARK
LITHUANIA
London
English Channel
Paris
Warsaw
Vienna
Budapest
Munich
AUSTRIA
ROMANIA
BULGARIA
CORSICA
SARDINIA
Rome
Naples
Adriatic
Palermo
SICILY
MALTA

IRE People

(*Continued from page 58A*)

Ben Davison (A'56) has been named to fill a new executive sales post at Electrodynamic Instrument Corp. He will be in charge of sales of precision test instruments, power supplies, wire wound components and custom industrial instrumentation systems.

B. Davison

Prior to joining EIC he served as branch sales manager for Koch Engineering and Sales Company; sales representative for Harrison Equipment Company, Inc., and with other electromechanical engineering organizations.

Mr. Davison is a member of the Geophysical Society of Houston.

❖

Packard Bell Computer Corporation has named **Kenneth R. Jackson** (M'46–SM'54) technical assistant to the director.

Jackson received the B.S. degree in electrical engineering from Wayne University in 1941 and the M.S.E.E. from the University of California in 1951. He is a registered professional engineer in the state of California, and a member of Tau Beta Pi and Sigma Xi. He holds several patents for missile autopilot devices.

K. R. Jackson

Before joining Packard Bell Computer he served as special assistant to the president of the Waugh Engineering Company, Van Nuys, Calif. Previously he was co-owner, president, and chief engineer of Dynalysis Development Laboratories, West Los Angeles, Calif. His experience also includes positions as chief project engineer at the J. B. Rea Company, Santa Monica Aviation, Inc., Downey, Calif.; and research engineer at the Naval Ordnance Laboratory, Washington, D. C.

❖

Gulton Industries, Inc., Metuchen, N. J., has announced that **J. Paul Jordan** (SM'55) has been elected a vice president. He will continue in his present position, as assistant to the president and scientific consultant for technical planning, and assume new executive duties.

Mr. Jordan joined the company in 1958 after nearly twenty years with General Electric Co., Syracuse, N. Y. He is vice chairman of the standards and electronics committee of the American Institute of Electrical Engineers.

❖

(*Continued on page 62A*)

IRE People

(Continued from page 60A)

Robert W. Deichert (S'47–A'49–M'55) has been appointed engineering manager for Scientific Instruments of the Industrial Electronics Division at Allen B. Du Mont Laboratories, Inc. In his new post he will have over-all engineering and design responsibilities for the company's oscilloscopes and related electronic test equipment and accessories. Prior to his new appointment he had been manager of the Data and Display Laboratory of Du Mont's Military Electronic Operations.

R. W. Deichert

He has been a member of the Du Mont organization since 1951. He participated in the design and development of test equipment and procedures for experimental multiplier photo tubes and the development of the AN/USA-5 (XN-L) television system. He designed and developed a Scintillation Rate Meter for the location and measurement of radio-activity, and has been responsible for the management of the Data and Display Laboratory, working primarily with specialized radar display systems, analog and digital data processing, servo system development, and the design of such peripheral equipment as transistorized power supplies, amplifiers, and computers.

Mr. Deichert is a graduate in Electrical Engineering of Pratt Institute, Brooklyn, N. Y., and he received a master's degree in Electrical Engineering from Stevens Institute of Technology, where he was also a guest lecturer. He is a member of the American Institute of Electrical Engineers, and the National Society of Professional Engineers.

❖

Richard T. Petruzelli (S'48–A'50) has replaced Mr. Deichert as manager of the Data and Display Laboratory.

Mr. Petruzelli was first associated with Du Mont in 1951. Prior to joining the Du Mont organization, he was a television engineer with the National Broadcasting Company. At Du Mont he has held positions as project engineer on bright display systems for air traffic control and the CAA, and as section manager on design and development of monochrome and color television equipment and industrial television and electronic automotive test equipment. At Curtiss-Wright Electronics he did radar simulation work on target generator systems,

R. T. Petruzelli

(Continued on page 64A)

NOW, FROM FAIRCHILD

PNP SILICON MESA TRANSISTORS

A "MIRROR IMAGE" OF AVAILABLE NPN CHARACTERISTICS

Same high-speed switching capabilities with which Fairchild startled the industry are now available in PNP — 80 milli-micro-second rise time, 2 watts dissipation, 300° C. survival. Fairchild Silicon Transistors are multiple solid-state diffused. Their mesa construction affords excellent heat dissipation and extraordinary ruggedness.

Complementary symmetry within computer circuit designs now affords another technique for reducing number of components and increasing reliability. The advantages of complementary symmetry have been well known, but the high performance silicon transistors that could take advantage of the technique have not been available.

Direct replacement of germanium by silicon is feasible now that high performance silicon PNP mesa transistors are readily available. In silicon transistor circuits, you need no longer hesitate to make use of the particular advantages of PNP polarity. Availability is firmly assured.

COMPETITIVE ADVANTAGES FOR YOUR DESIGNS either in terms of price or functional efficiency are a likelihood that you should investigate. PNP silicon transistors with these speed-power characteristics have not been generally available, hence until now it has not been possible to design circuits using the complementary symmetry concept.

Special attention will be given to inquiries received on company letterhead.

PNP — 2N1131, 2N1132

Symbol	Specification	Rating	Characteristics	Test Conditions
V_{CE}	Collector to Emitter voltage (25° C.)	30v		
P_C	Total dissipation at 25° C. Case temp.	2 watts		
h_{FE}	D.C. current gain		2N1131—15 to 45 2N1132—30 to 90	I_C 150ma V_C 10v
R_{CS}	Collector saturation resistance		6 Ω typical 10 Ω max.	I_C 150ma I_B 15ma
h_{fe}	Small signal current gain at f=20Mc		2.5 typical	I_C 50ma V_C 10v

NPN — 2N696, 2N697

Symbol	Specification	Rating	Characteristics	Test Conditions
V_{CE}	Collector to Emitter voltage (25° C.)	40v		
P_C	Total dissipation at 25° C. Case temp.	2 watts		
h_{FE}	D.C. current gain		2N696—20 to 60 2N697-40 to 120	I_C 150ma V_C 10v
R_{CS}	Collector saturation resistance		3.5 Ω typical 10 Ω max.	I_C—150ma I_B—15ma
h_{fe}	Small signal current gain at f=20Mc		5 typical	I_C—50ma V_C—10v

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FAIRCHILD SEMICONDUCTOR CORPORATION

IRE People

(*Continued from page 62A*)

operator training requirements, and design of a radar maintenance trainer.

Mr. Petruzelli is a graduate of Newark College of Engineering, Newark, N. J., where he received the B.S. degree in Electrical Engineering. He did graduate work there and at Stevens Institute of Technology, Hoboken, N. J.

❖

Frederick R. Lack (A'20–F'37) has been elected a director of the Sprague Electric Company.

He is a former director and vice-president of the Western Electric Company, manufacturing arm of the American Telephone and Telegraph Company. He retired in August, 1958, after having been associated with the Bell System since 1911.

F. R. Lack

Following service as a lieutenant in the U. S. Army Signal Corps in France during World War I, he received the B.S. degree (Magna Cum Laude) from Harvard University in 1925. He received the honorary degree of Doctor of Science from Albright College in 1958.

During World War II he served in Washington as director of the Army-Navy Electronics Production Agency (ANEPA). From 1925 to 1938, he was a member of the staff of the Bell Telephone Laboratories. Here he was responsible for the introduction of quartz crystals as the frequency controlling elements in critical electronic circuitry. He was later in charge of vacuum tube development, reporting directly to Dr. Mervin Kelly, BTL director of research. He was also in charge of designing and building the first commercial ship-to-shore radio telephone, installed on the liner S. S. Leviathan.

He has been active in industry and other associations. He has served as chairman of the Joint Electronics Industries Committee, as president of the American Standards Association, and as vice-president and director of the Electronic Industries Association. In June, 1959 he received the Medal of Honor of the Electronic Industries Association for his many contributions to progress in the electronics industry. He was also director and member of the executive committee of the Armed Forces Communications and Electronics Association and served as a member of the executive committee and director of the National Security Industrial Association.

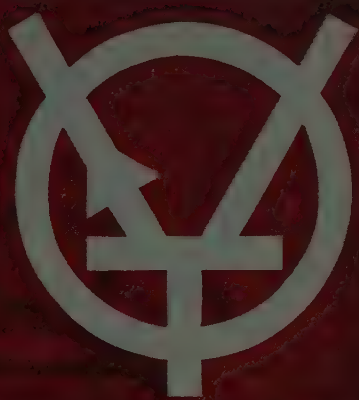
He has been a director of the Hazeltine Corporation since October, 1958.

His interest in education has included being on the visitors' committee for the

(*Continued on page 66A*)

ow PHILCO OFFERS BOTH

AND



HIGH FREQUENCY SILICON TRANSISTORS

For High Temperature Applications

TYPES:

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Immediately available off-the-shelf, in quantities of 1 to 99, from your local Philco Industrial Semiconductor Distributor.

- **LOW SATURATION RESISTANCE**
- **LOW COLLECTOR CAPACITANCE**
- **UNIFORM CHARACTERISTICS**
- **HIGH RELIABILITY**

For reliable performance in military and commercial circuits subject to high environmental temperatures, Philco now offers a full range of high frequency switching and amplifying silicon transistors . . . in both PNP and NPN types (SAT* and SADT**).

In high speed circuits, the switching types provide the lowest saturation resistance at high junction temperatures . . . permitting up to 5 mc pulse rates using saturated configurations and up to 30 mc pulse rates with non-saturating techniques.

The excellent high frequency response of the amplifier types permits the practical design of communications systems at frequencies up to 60 mc.

For complete data and application information, write Dept. IR-1059.

*Trademark Philco Corp. for Surface Alloy Transistor.
**Trademark Philco Corp. for Surface Alloy Diffused-base Transistors.

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(Continued from page 64A)

Board of Overseers of Harvard College, and a national sponsor for the Harvard Foundation for Advanced Study and Research, as well as being past president of the Harvard Engineering Society.

Mr. Lack served two terms as director of the IRE. He is also a member of the AIEE, of the American Association for the Advancement of Science, of the American Physical Society, and of the Harvard Engineering Society.

❖

Lawrence R. Krahe (M'52–SM'55), sales engineer, will be in charge of the new Washington office of Andrew Corporation, which will be located in Bethesda, Md. He has extensive engineering experience in antenna system design, acquired during his eleven-year association with the Andrew Corporation. Prior to his new appointment, he was Chief Engineer of the Advance Development Group, Chief Administrative Engineer, and most recently, sales engineer in the company's Chicago office.

L. R. Krahe

Mr. Krahe is a graduate engineer from Illinois Institute of Technology, and holds a master's degree in business administration from the University of Chicago.

❖

William Kneen (M'49–SM'56) has been appointed chief project engineer, Analytical and Control Instrument Div. of Consolidated Electrodynamics Corporation.

Kneen joined CEC in January, 1954, as a training engineer. He became an application engineer in November, 1954; supervisor of a digital instrumentation group in 1956; and an engineering group supervisor with the Analytical and Control Instrument Div. in 1958.

W. Kneen

Previously, he was an instrumentation and analysis engineer with Pullman Standard Car Manufacturing Co., and a development engineer with Aurex Corp. and AMI, Inc.

Kneen has the B.S. and M.S. degrees in electrical engineering from the Illinois Institute of Technology. He is a member of the Instrument Society of America.

❖

(Continued on page 69A)

MICROWAVE GENERATORS

950 to 21,000 mc

with MORE MODULATION CAPABILITIES

he extremely wide range of pulse width, delay and repetition rate are read directly on the front panel of Polarad icrowave generators. In addition these units provide roadband internal FM and CW modulation, versatile exteral modulation capability and a sync output for all signals. hese features provide the largest choice of microwave st signal combinations available in signal generators.

nternal pulse rise and decay: 0.1 microsecond.*

xternal pulse modulation: positive or negative polarity, 0 to 10,000 pps, 0.2 to 100 microseconds width.*

utput synchronization pulses: positive polarity, delayed nd undelayed.

ugged construction. Quick, easy inspection and servicing. ontinuous UNI-DIAL tuning in each frequency range. Nonontacting tuning cavity chokes.

or every application, 950 to 21,000 mc.

Model	Frequency Range	Power Output
ISG-1	950 to 2,400 mc	0 dbm (1 milliwatt) to —127 dbm, directly calibrated
ISG-2	2,000 to 4,600 mc	
MX	6,950 to 11,000 mc	
ISG-34	4,200 to 11,000 mc	
MK	10,000 to 15,500 mc 15,000 to 21,000 mc	+10 dbm (10 milliwatts) to —90 dbm

ID MICROWAVE POWER SOURCES—1,050 to 17,500 mc.

gh power output: 14 to 700 milliwatts depending on frequency. **Modulation:** Internal square wave or external FM d square wave.

MODULATION CAPABILITIES*

Generates CW, FM, internal pulse, internal square wave. Or can be externally modulated.

Pulse delay: adjustable from 2 to 2,000 microseconds.

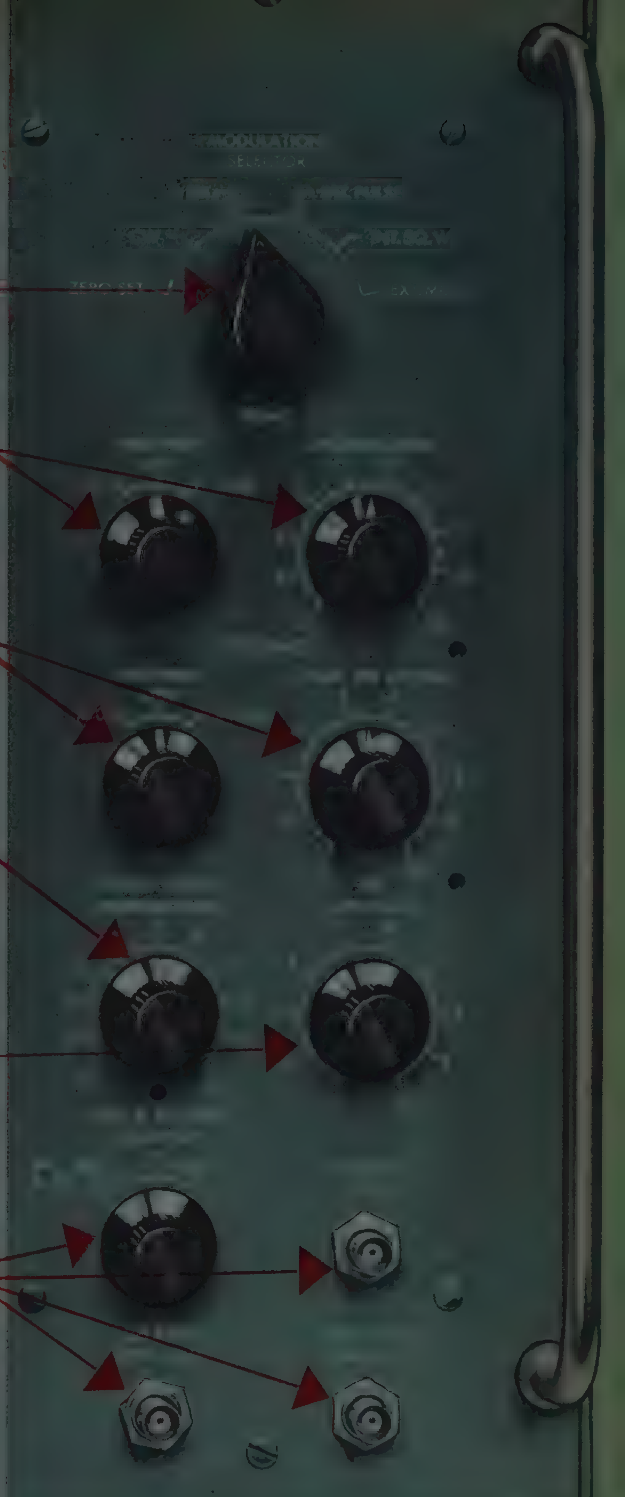
Pulse repetition rate: adjustable from 10 to 10,000 pps.

Pulse width: adjustable from 0.2 to 10 microseconds.

Linear sawtooth internal FM modulation, 10 to 10,000 cps, 5 mc minimum frequency deviation.

Internal or external, pulse or sine wave synchronization.

*Models MSG-34, PMX and PMK



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☐ Microwave Signal Generators, ________ to ________ mc

☐ Microwave Power Sources, ________ to ________ mc

My application is: ________

Name ________

Title ________ Dept. ________

Company ________

(Continued from page 66A)

Knox McIlwain (A'31–M'40–SM'43–F'48), a ballistic missile and electronic expert, today was appointed special representative for Burroughs Corporation, to represent the Detroit business machine and computer manufacturer on special boards and organizations. He will assume his new duties immediately.

He was formerly manager of special products, primarily concerned with all engineering development and design projects in the military field of digital communications, weapons systems, air defense instrumentation, airborne control systems, telemetering and automation.

He was associated with Hazeltine Electronic Corp. as chief consulting engineer before joining Burroughs early in 1956. From 1924 to 1941 he was a professor at the Moore School of Electrical Engineering, U. of Pennsylvania.

He has had extensive experience in all facets of electronics, and holds numerous patents in the electrical and electronic field, as well as having written three different engineering handbooks. He is a graduate of Princeton and the University of Pennsylvania.

He is a past vice president of the Institute of Navigation.

❖

Kenneth G. McKay (M'47–SM'58) has been elected Vice President in charge of Systems Engineering of Bell Telephone Labs., effective September 1.

A research physicist, he has been associated with electronic, semiconductor and solid state research and development programs at Bell Labs. since 1946.

He is a native of Montreal, Canada, and a graduate of McGill University, where he received the B.S. and M.S. degrees in 1938 and 1939, respectively. He was awarded the Sc.D. degree by MIT in 1941 and worked with the National Research Council in Canada for the next five years.

Upon joining Bell Laboratories in 1946 he undertook fundamental research studies of the physics of solids, including studies of secondary electron emission and electron bombardment conductivity in insulators and semiconductors. Later his work related to the electrical and optical characteristics of electrical breakdown in germanium and silicon.

He was named director of development of solid state devices in 1957 and promoted to director of development of components and solid state devices in 1958.

Dr. McKay has been granted nine patents for his electronic inventions, and has written extensively on solid state physics for scientific publications.

He is a Fellow of the American Physical Society and served on the board of editors of *The Physical Review* from 1955 to 1957. He is also a member of the Research Society of America.

❖

(Continued on page 70A)

IRE People

(Continued from page 69A)

The appointment of **Dr. Louis Malter** (A'37–SM'45–F'52) to head a new Vacuum Products Division, which he was responsible for setting up, was announced today by Varian Associates President H. Myrl Stearns. Dr. Malter joined Varian in May, 1958, as director of Central Research, coming to the firm from his post as chief engineer of the RCA Semiconductor and Materials Division.

L. MALTER

Prior to his last position with RCA, Malter served as assistant director of the RCA Electronics Research Laboratory, manager of gaseous electronics research and manager of microwave tube development. He received the B.A. degree from College of the City of New York, and holds M.A. and Ph.D. degrees from Cornell University. He was presented the Ward medal in physics by CCNY and held the White and Hecksher Fellowships in physics at Cornell. He is a member of the American Physical Society and Sigma Xi.

At Varian, in addition to serving as director of Central Research, Dr. Malter was responsible for setting up the Vacuum Products Division.

❖

Dr. Lauriston C. Marshall (SM'50) has become Associate Technical Director of the Microwave Power Lab. of Varo Mfg. Co., Inc. Varo has recently established the Microwave Power Laboratories to exploit many hitherto unexplored concepts in the very high power microwave field.

L. C. MARSHALL

Dr. Marshall has conducted research in microwave radiation, nuclear radiation, the technical aspects of musical tone production; the basic properties of malleable iron; environmental control for plant growth; and electron physics, particularly the field of gaseous conduction.

He was born in China, where his parents were missionaries. He is a graduate of Park College and obtained the Ph.D. degree in Physics from the University of California, Berkeley, and did post-doctoral study as a National Research Fellow in Physics at Princeton University.

From 1931 to 1937 he served as Physi-

(Continued on page 72A)

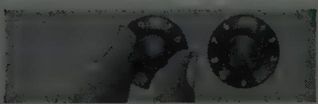
10 Mc Counter displays microwave frequencies

to transfer oscillator

Coupled to a computing transfer oscillator, this counter will display the 13,213.45Mc reading shown...one more instance of the unique utility of Model 7370.


1

2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SPEEDY, PRECISE METHOD

1. Operator tunes transfer oscillator in the conventional way—finds two adjacent fundamentals having harmonics that zero-beat with the unknown frequency.

2. Reads harmonic number appearing on built-in automatic calculator.

3. Sets digital switches to harmonic number.

4. Reads microwave frequency as it appears on the face of the counter. The entire procedure takes less than one-fifth the time ordinarily required.

SPECIFICATIONS

Model 7370 used with transfer oscillator (Model 7580)

Frequency measuring range	dc to 15KMc
Types of signals accommodated	CW, AM, FM, pulsed r–f
Sensitivity	100 mv rms
Input impedance	50 ohms
Accuracy	up to $\pm$ 3p in 10^7
Fundamental range of trans. osc.	75 to 150 Mc & 7.5 to 15 Mc
Harmonics available	up to 100th
Stability of fundamental	.0001% per min

Model 7370 alone

Frequency counting range	dc to 10Mc
Sensitivity	selectable: 0.1v, 1v & 10v
Input impedance	10M ohms
Stability of time standard	3 parts in 10^7 per week
Additional functions	Measures period, phase & frequency ratio. Times interval between independent signals.

Prices

Model 7370 Universal EPUT® & Timer	$1975
Model 7580 Computing Transfer Oscillator	$1650

Write for detailed technical bulletins

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T22

IRE People

(Continued from page 70A)

cist on the staff of the Bureau of Plant Industry, U. S. Dept. of Agriculture, where he first became interested in problems of solar radiation as related to controlled environment for plant growth and other biophysical problems. This research led to a commercially used system for air-conditioning greenhouses in full sunlight—and the subsequent development of such controlled environment laboratories as those at the California Institute of Technology and at the University of Wisconsin.

He served as Professor of Electrical Engineering at the University of California, Berkeley, from 1937 to 1954. During World War II, from 1941 to 1945, he was on the staff of the Radiation Laboratory of the Massachusetts Institute of Technology, where he served as Head of the Division responsible for the development of radar systems for coastal defense, air search against submarines and shipborne installations. While at MIT he collaborated with Dr. Luis W. Alvarez in developing the first working model of Ground Control Approach (GCA) radar and in arranging for the initial steps of production, including the construction of the first models and the training of personnel.

He was subsequently sent to England as Chief of the British Branch of the Radiation Laboratory. His duties there included getting radar ready for the invasion of Europe, including precision bombing radar and navigational techniques; installation of the first MEW long range early warning radar; and the introduction of radar beacons and artillery ranging techniques, and the introduction of countermeasures against the buzz bombs. In the later stages of the war, he served as chief of the Operations Research Section of the United States Armed Forces, Pacific Ocean Areas.

On return to the University of California in 1946, Dr. Marshall set up and supervised the curriculum in Engineering Physics, established and directed the Microwave Laboratory, and served as staff member of the University's Radiation Laboratory, specializing in the design and construction of very high energy particle accelerators in the multi-million and billion volt range. These included the first proton linear accelerator and planning of the Bevatron.

Before his association with Varo, he was Director of Research of the Link Belt Company, where he set up a basic physical research and testing laboratory for this company operating in the field of plant automation, materials handling equipment, and materials research.

As recognition of his scientific accomplishments, Dr. Marshall has received several citations. He has been a Whiting Fellow, a National Research Council Fellow; he has received a Guggenheim Fellowship and is currently a Fellow of the American Physical Society. For his contributions during the War, Dr. Marshall re-

(Continued on page 74A)

IRE People

(*Continued from page 72A*)

ceived a special citation in 1945 from the Pacific Theater Commander and one from the Office of Scientific Research and Development headed by Dr. Vannevar Bush. In 1948 Dr. Marshall received the Presidential Certificate of Merit, and in 1952 was selected by Park College as its Distinguished Alumnus. Dr. Marshall is a Fellow of the American Physical Society and a member of the American Institute of Electrical Engineers, the Society of Automotive Engineers, the American Chemical Society, the Acoustical Society of America, the Society of Motion Picture and Television Engineers, the Operations Research Society, and the American Society for Testing Materials, of which he is Vice-Chairman of Committee A-7 on Malleable Iron, a member of Committee E-9 on Fatigue of Materials, and a member of the Ohio Valley District (15) Council. His honor societies include: Sigma Xi, RESA, Eta Kappa Nu and Gamma Alpha.

❖

S. Edwin Piller (A'48–M'55) was recently appointed group supervisor of the SSB Section of the Eldico Electronics Division of the Radio Engineering Laboratories. He was formerly in the Radio and Allocations Engineering Department of N.B.C.

S. E. PILLER

A licensed amateur radio operator (W2KPQ) since 1937, he received an award last year from the Chief Signal Officer for his work in the planning, organization and direction of the First U. S. Army MARS SSB Technical Net. He is also President of the SSB Amateur Radio Association and former editor of its monthly newsletter.

Mr. Piller is a member of A.F.C.E.A. and the Radio Club of America.

❖

H. J. Ridinger, Jr., (M'58) has joined the advertising and public relations department of The Thompson-Ramo-Wooldridge Products Company as technical publications supervisor. He has had several years' experience in technical writing with Space Technology Laboratories, The Ramo-Wooldridge Corporation, and Hoffman Electronics, all in Los Angeles. A native of Los Angeles, he received the A. A. degree in 1955 from El Camino College where he majored in engineering.

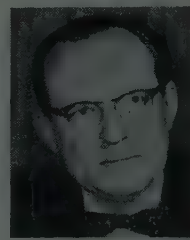
❖

(*Continued on page 76A*)

IRE People

(Continued from page 74A)

Frank L. Marx (A'41–SM'47), Vice-President in charge of Engineering, American Broadcasting Company, has been elected a director of Foto-Video Labs., Inc.



F. L. Marx

In 1924 he was an Operator-Engineer for WPAB and WRCV at Norfolk, Va., before coming to New York as Chief Engineer for WMCA, New York City. He became technical advisor of WJZ (Blue Network) in 1944, then Director-General of Engineering of ABC in 1945. He was elected an ABC Vice-President in 1948. He is a consultant of various technical committees in radio and broadcasting, and a member of several engineering and scientific organizations. He is also a member of the Washington, D. C. Professional Engineering Society.

❖

Milton E. Mohr (M'45–SM'53), vice president of engineering for Ramo-Wooldridge was awarded an honorary doctor of engineering degree by the University of Nebraska at its eighty-eighth annual commencement for his important contributions in the engineering field, and for his civic and industrial leadership.

M. E. Mohr

Dr. Mohr's engineering contributions include research and development on telephone transmission and switching, and the application of electronic devices to telephone switching. He also did pioneering work on germanium diodes, transistors and gas tubes. For these contributions, he was listed in "Who's Who in Engineering" for 1954.

He has been with Ramo-Wooldridge since 1954. He joined the corporation as director of control systems, and was made vice president of engineering for the R-W division in 1958 at the time of the merger of Ramo-Wooldridge and Thompson Products, Inc. to form Thompson Ramo Wooldridge Inc.

Prior to 1954, he was a department head in the radar laboratory of Hughes Aircraft Company where, for four years, he contributed to the development of advanced interceptor fire control systems. From 1938 to 1950, he was a member of the technical staff of the Bell Telephone Laboratories, New York, N. Y.

Dr. Mohr received the B.S. degree in electrical engineering from the University of Nebraska in 1938. He had the highest

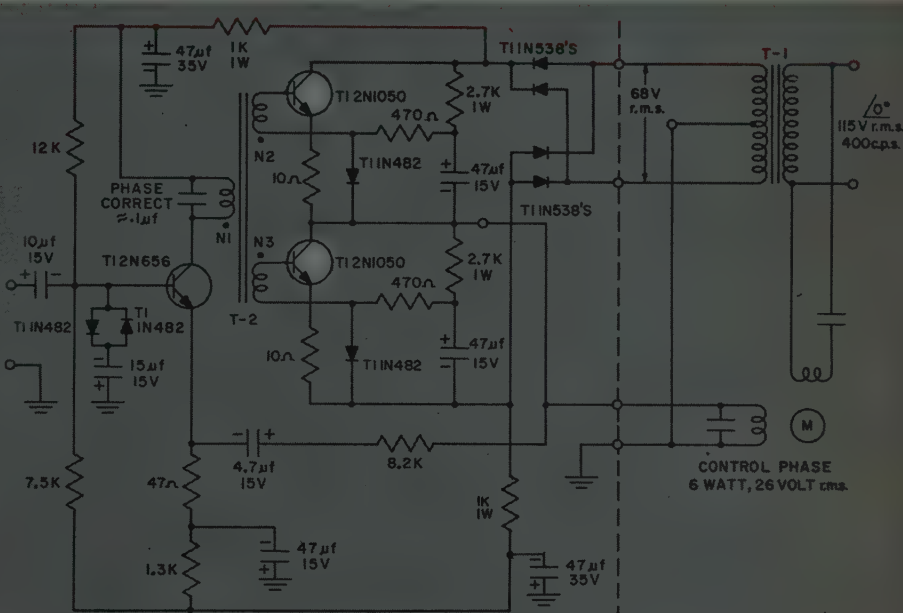
(Continued on page 78A)

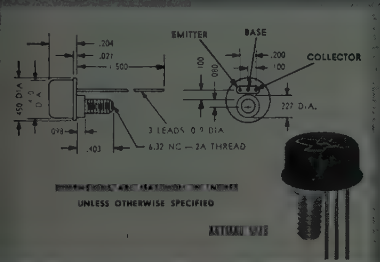
How to get 55% over-all efficiency in transistorized 6-watt servo amplifier

HIGH-EFFICIENCY SERVO CIRCUIT REQUIRES . . .

- no output transformer
- no center-tap motor winding

Higher over-all efficiency than in a conventional Class-B push-pull amplifier is achieved in this servo by use of unfiltered rectified a-c for current supply voltage—with resulting reduction in size, weight and power supply requirements. This higher efficiency means greater transistor reliability, smaller heat sink and/or higher allowable ambient temperatures. Output will remain sinusoidal when amplifier is overdriven.





TRANSFORMERS

T-1 400 cps, 12-watt power transformer step-down 115 volt to 68 volt c.t.

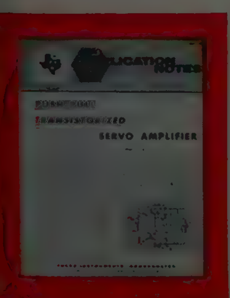
T-2 400 cps, 65-mw driver transformer. Turns ratio N1: N2: N3 = 2: 1: 1
Primary Current = 10 ma d-c. Primary Inductance = 1.5 hy.

...with TI 2N1050 N-P-N silicon transistors!

Exclusive TI 2N1047 intermediate-power series now gives you maximum design flexibility plus high efficiency . . . all in a miniature package!

Consider the design flexibility made possible by the exclusive features of this series . . . 40 watts dissipation at 25°C case temperature . . . unique stud mounting for maximum thermal efficiency . . . 80- and 120-volt BV_{CEX} . . . 15-ohm R_{CS} . . . –65°C to +200°C operating and storage range . . . choice of beta spreads.

Apply TI's guaranteed specs to your design situations today. This use-proved series is available off-the-shelf — *at factory prices* — in 1-999 quantities from your nearby authorized TI distributor, and in production quantities from your TI sales office.



Write on your company letterhead for illustrated TI APPLICATION NOTES on the transistorized servo amplifier.

PARAMETER	TEST CONDITIONS		2N1047 min.	2N1047 max.	2N1048 min.	2N1048 max.	2N1049 min.	2N1049 max.	2N1050 min.	2N1050 max.	unit
BV_{CEX} Breakdown Voltage	$I_C = 250\ \mu a$	$V_{BE} = -1.5V$	80		120		80		120		v
BV_{EBO} Breakdown Voltage	$I_E = 250\ \mu a$	$I_C = 0$	10		10		10		10		v
I_{CBO} Collector Cutoff Current	$V_{CB} = 30V$	$I_E = 0$		15		15		15		15	µa
h_{FE} Current Transfer Ratio †	$V_{CE} = 10V$	$I_C = 200ma$	12	36	12	36	30	90	30	90	—
h_{IE} Input Impedance †	$V_{CE} = 10v$	$I_B = 8ma$		500		500		500		500	ohm
R_{CS} Saturation Resistance †	$I_C = 200$ ma	$I_B = 40ma$		15		15		15		15	ohm
V_{BE} Base Voltage †	$V_{CE} = 15v$	$I_C = 500ma$		10		10		10		10	v

†Semiautomatic testing is facilitated by using pulse techniques to measure these parameters. A 300-microsecond pulse (approximately 2% duty cycle) is utilized. Thus, the unit can be tested under maximum current conditions without a significant increase in junction temperature, even though no heat sink is used. The parameter values obtained in this manner are particularly pertinent for switching circuit design and, in general, indicate the true capabilities of the device.

germanium and silicon transistors
silicon diodes and rectifiers
tan-TI-cap solid tantalum capacitors
precision carbon film resistors

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IRE People

(Continued from page 76A)

scholastic average attained in the University's college of engineering and architecture for a thirty-seven year period from 1922 to 1959.

In 1948 he received honorable mention in the Eta Kappa Nu awards for the nation's outstanding young electrical engineer.

He is a member of the American Institute of Electrical Engineers, the New York Academy of Sciences, and the American Rocket Society. He is also a member of Sigma Tau, Sigma Xi, Eta Kappa Nu and Pi Mu Epsilon professional fraternities. In addition, he is the holder of twenty-two patents, and author of several technical articles.

❖

McLean Engineering Laboratories, Inc. of Princeton, N. J. has appointed **James G. Robinson** (S'42–A'44–M'55) as technical assistant to the president and company procurement director. He holds a B.S.E. and an M.S.E. in electrical engineering from Princeton University, for 9 years he was a director of procurement and government contract administration for the Applied Science Corp. of Princeton (ASCOP). From 1948 to 1950 he was contract administrator for the New York office of the AEC, negotiating with industry for the development of nuclear weapons. Prior to that he was a Research Assistant in Physics on various government projects and an instructor in electrical engineering.

J. G. ROBINSON

Mr. Robinson is a member of the A.I.E.E. and the New York and National Associations of Purchasing Agents.

❖

Lee D. Smith (S'48–A'50–M'54–SM'57) has joined the technical staff of Ramo-Wooldridge, a division of Thompson Ramo Wooldridge Inc.

He was formerly assistant chief engineer, Electronics Division and head of the Navigation Laboratory at Stromberg-Carlson. Previously, he was with the Diamond Ordnance Fuze Laboratories and its predecessor, the Advance Electronics Division of the National Bureau of Standards, in Washington, D.C.

He received the B.S. degree in electrical engineering from George Washington University in 1949. He has served as secretary-treasurer and vice chairman of the IRE Rochester Section. He is a member of the American Ordnance Association.

❖

(Continued on page 80A)

IRE People

(Continued from page 78A)

Dr. Charles H. Townes (SM'58), a Columbia University physics professor, will receive a Stuart Ballantine Medal from The Franklin Institute for his development of the maser, a sensitive and precise measuring device used to gather new information on planets and galaxies and to test cosmological theories. He will be awarded the medal at formal Institute ceremonies on October 21, 1959.

C. H. TOWNES

The medal citation to Dr. Townes reads: "For his conception and demonstration of the feasibility of securing amplification and generation of high frequency radio waves by stimulated emission of radiation and for his invention of the maser which represents a new departure in electronic procedures and which has already led to many fruitful scientific and practical uses."

The National Aeronautics and Space Administration hopes to place an atomic clock, based on Dr. Townes' maser, into orbit within two years. Experiments with the clock are expected to give Albert Einstein's general theory of relativity one of its most searching checks of its forty-three year history.

The Stuart Ballantine Medal, which Dr. Townes will receive, was founded in 1946 by the Boonton Foundation. It is awarded by The Franklin Institute for outstanding achievement in fields of communications which employ electro-magnetic radiation.

Dr. Townes was born July 28, 1915, in Greenville, S. C. He received the B.A. degree from Furman University in 1935, the M.A. degree from Duke University in 1937, and the Ph.D. degree from California Institute of Technology in 1939.

After obtaining his Doctorate, Dr. Townes became a technical staff member of Bell Telephone Laboratories. In 1948, he joined Columbia University as an Associate Professor of Physics. Two years later, he was named Professor of Physics, the position he still holds.

Dr. Townes served as Executive Director of the Columbia Radiation Laboratory from 1950 until 1952, and as Chairman of the Department of Physics at Columbia University from 1952 to 1955.

Author of more than 100 papers, Dr. Townes' book on Microwave Spectroscopy was published in 1955. Dr. Townes has been honored many times for his scientific accomplishments:

He was an Adams Fellow in 1950; National Lecturer, Sigma Xi, 1951; Summer Lecturer, University of Michigan, 1952; Guggenheim Fellow, 1955–56; Fulbright Lecturer, University of Paris, 1955–56; Fulbright Lecturer, University

(Continued on page 82A)

Need Tantalum Capacitors?

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Leader in tantalum capacitor technology, Mallory offers the broadest line on the market . . . ranging from micro-miniature Type HAT to the high-capacitance Type XTV. Included are 200° C ratings, pioneered by Mallory, in many case styles and values. Write today for technical data, and for a consultation.

Type	Description	Capacity Range	W. Volts DC Rating at 85°C	Temperature Range	Case Style	Body Length	Body Diameter
HAT	Pellet Anode—Liquid Electrolyte	1-10 mfd.	16-1V.	—20 to +85°C	Metal Case—Axial Leads—Insulated Case	.210″ max.	.075″ max.
TAS	Pellet Anode—Solid Electrolyte	.33-330 mfd.	35-6V.	—80 to +85°C	Metal Case—Axial Leads	.250″ to .750″	.125″ to .341″
TAM	Pellet Anode—Solid Electrolyte	6.8-56 mfd.	25-6V.	—55 to +85°C	Dip Coated Resin—Upright Mounting	.175″ thick	.313″ square
TAF	Foil Anode—Semi-Liquid Electrolyte	.25-440 mfd.	150-3V.	—55 to +85°C	Metal Case—Axial Leads	.688″ to 2.750″	.188″ to .375″
STNT	Pellet Anode—Liquid Electrolyte	2-40 mfd.	50-3V.	—55 to +85°C	Metal Case—Axial Leads	.350″	.155″
TNT	Pellet Anode—Liquid Electrolyte	4-80 mfd.	50-3V.	—55 to +85°C	Metal Case—Axial Leads	.500″	.155″
TAP	Pellet Anode—Liquid Electrolyte	2-30 mfd.	90-6V.	—55 to +85°C	Metal Case—Axial Leads	.500″	.238″
TAP2	Pellet Anode—Liquid Electrolyte	11-140 mfd.	90-6V.	—55 to +85°C	Metal Case—Axial Leads	.660″	.238″
M2	Pellet Anode—Liquid Electrolyte	11-140 mfd.	90-6V.	—55 to +150°C	Metal Case—Axial Leads	.500″	.290″ (Body) .484″ (Flange)
XTK	Pellet Anode—Liquid Electrolyte	2-70 mfd.	340-8V.	—55 to +175°C	Metal Case—Axial Leads or Terminal	.438″ to 1.313″	.650″
XTM	Pellet Anode—Liquid Electrolyte	4-140 mfd.	340-8V.	—55 to +175°C	Metal Case—Axial Leads or Terminal	.563″ to 1.781″	.650″
XTL	Pellet Anode—Liquid Electrolyte	3.5-120 mfd.	630-18V.	—55 to +200°C	Metal Case—Axial Terminal	.500″ to 2.595″	.875″
XTH	Pellet Anode—Liquid Electrolyte	7-240 mfd.	630-18V.	—55 to +200°C	Metal Case—Axial Terminal	.688″ to 4.063″	.875″
XTV	Pellet Anode—Liquid Electrolyte	18-1300 mfd.	630-30V.	—55 to +175°C	Metal Case—Axial Terminal	.563″ to 2.750″	1.125″
XTO	Pellet Anode—Liquid Electrolyte	7-240 mfd.	630-18V.	—55 to +200°C	Metal Case—Axial Terminal	.563″ to 2.750″	1.125″

Mallory Capacitor Company

Indianapolis 6, Indiana

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MALLORY

IRE People

(Continued from page 80A)

of Tokyo, 1956; and Richtmyer Lecturer, American Physical Society, 1959.

He received the Research Corporation Annual Award in 1958; Page One Award for Science, 1958; Morris Liebman Memorial Prize of the IRE, 1958; Comstock Award of the National Academy of Sciences, 1959; and Exceptional Service Award, U. S. Air Force, 1959.

Among the organizations in which Dr. Townes holds membership are: American Physical Society (Fellow), Societe Française de Physique, Physical Society of Japan, National Academy of Sciences and American Academy of Arts and Sciences.

❖

O. F. Vogel, Jr. (SM'57) has joined Digital Instrument Laboratories of East Los Angeles as sales manager. He left his post as senior group engineer at Electronic Engineering Company to assume his new position. During the more than eight years he spent at Electronic Engineering he managed the $3.5 million Project Datum, which included installation of a centralized data processing system at Edwards Air Force Base. He was in charge of an enginering group responsible for the design and production of research and development data processing equipment and during the last year he participated in R and D sales and applications engineering. He is a graduate of the University of Southern California.

O. F. Vogel, Jr.

❖

Dr. James R. Wait (SM'56), Consultant to the Director of the National Bureau of Standards' Central Radio Propagation Laboratory, has received a Gold Medal (for exceptional service) from the U. S. Department of Commerce. He was cited for "highly distinguished authorship in the field of radio propagation."

He has published over 100 papers. In the recent reorganization of the Bureau's *Journal of Research* into a four-part publication, he was made editor of part "D." This section deals with research in radio propagation and communications and with upper atmospheric physics. Other sections are Physics and Chemistry, Mathematics and Mathematical Physics, and Engineering and Instrumentation.

Born in Ottawa, Canada, in 1924, he received the B.A.S. and M.A.S. degrees in engineering physics in 1948 and 1949, respectively, and the Ph.D. degree in electromagnetic theory in 1951, all from the University of Toronto.

Dr. Wait joined the Bureau in 1955, as a consultant in the Radio Propagation

(Continued on page 84A)

DELCO RADIO

POWER TRANSISTORS

Unsurpassed Performance, Widest Applications, Military Types

Delco Radio has a complete line of germanium power transistors

HIGH POWER—The conservatively rated 15 ampere stud-mount series leads the field with improved collector to emitter voltages, low saturation resistances, and diode voltage ratings measured at 85°C. The JAN 2N174, MIL-T-19500/13A, and the commercial 2N174 are leaders in the switching versions of this series. Headed by the 2N1100 and including the new 2N1412, other transistors in the Delco Radio high power family have equally impressive performance characteristics.

MEDIUM POWER—The new 5-ampere series in the JEDEC TO3 case includes the 2N1168 and 2N392 for high power gain in low distortion linear applications. The 2N1011 (MIL-T-19500/67 Sig.C), 2N1159, and 2N1160 for higher voltage switching applications complete this series. • The low diode leakage 2N553 series, also in the JEDEC TO3 case, is rated up to 4 amperes. Usage of this series is growing rapidly in a variety of applications—especially in regulators. The 2N297A (MIL-T-19500/56 Sig.C) and the 2N665 (MIL-T-19500/38 Sig.C) are produced from this type, making with the above a comprehensive line for military applications.

MINIATURIZED MIGHT—The new 2N1172 is a mighty mite for a wide variety of usages where the modified JEDEC 30 package, on a functioning miniature diamond base, permits dissipation up to two watts at 70°C.

Write today for engineering data or personal applications assistance in getting these readily available, *proved* transistors to work in your most exacting requirements.

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Santa Monica, California
726 Santa Monica Boulevard
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IRE People

(*Continued from page 82A*)

Engineering Division. He is past president of the Boulder, Colo. chapter of RESA, a member of the Canadian Association of Physicists, the Society of Exploration Geophysicists, Commission III, URSI, on Ionospheric Wave Propagation, and Commission VI, Electromagnetic Theory.

❖

A. D. Watt (SM'54), electronic scientist and former section chief, has been appointed assistant chief of the radio communication and systems division, central Radio Propagation Lab. at the National Bureau of Standards' Boulder Laboratories.

A. D. WATT

A specialist in the study of low frequency propagation and modulation techniques, he will assume his new position with 12 years of work in organizing and carrying out successful engineering research. His new responsibilities will be of a technical advisory nature for the division. His primary concern will be with the technical and administrative aspects of studies on communication theory, modulation techniques, and low frequency propagation.

As chief of the modulation systems section in CRPL's radio propagation engineering division for the last three years, he led a group whose essential investigations were concerned with the study of very low frequency communication possibilities and the modulation problems and performance of tropospheric scatter communication systems.

Prior to joining the Bureau of Standards in 1951, he was in charge of a graphic communication group at the Naval Research Lab. His work there covered research in communication design problems, communication theory and methods of transmitting graphical material, including facsimile, radio photography, and television. His professional career at NRL was interrupted by a year of service with the U. S. Navy as an Ensign, assigned to work in research and development of facsimile and transmitting equipment.

A graduate in electrical engineering from Purdue University, he is the author of a number of papers which have appeared in the TRANSACTIONS and PROCEEDINGS OF THE IRE, the *NBS Journal of Research* and NBS reports.

His professional activities include membership on the U. S. Navy Polaris Command Communication committee, Study Groups 1, 3, 7, and 9 of the Consultative Committee on International Radio (CCIR), Commission IV of International Scientific Radio Union (URSI), Research Society of America, and Eta Kappa Nu.

❖

(*Continued on page 86A*)

THE SEARCH . . .

Your attention is invited to a limited number of senior positions created by Raytheon Government Equipment Division's current expansion.

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EXCELLENCE IN ELECTRONICS

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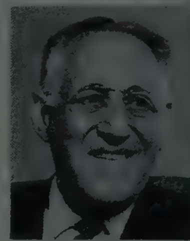
IRE People

(Continued from page 84A)

Dr. Irving Wolff (A'27–VA'39–F'42,) Vice President, Research, the RCA Labs., whose basic contributions to the field of electronics range from improvements on the loudspeaker to the initiation of the first successful use in the United States of microwave radar, will receive an Elliott Cresson Medal from The Franklin Institute. He will be awarded the medal at formal Institute ceremonies on October 21.



I. Wolff

The medal citation to Dr. Wolff reads: "In consideration of his many important contributions to the science of electronics as evidenced by his productiveness over a period of many years in many diverse fields such as acoustics, optics, radio, infrared detection and radio frequency hearing, and especially in view of his pioneering work in the centimeter wave field and his contributions to microwave radar development."

Holder of about 80 patents, in 1934 he demonstrated pioneer radar equipment to the U. S. Army Signal Corps at Atlantic Highlands, N. J., using reflected waves to locate and follow the progress of a boat sailing into New York Bay about a half a mile offshore.

He and his associates continued their work in radar, and in 1938 contributed to the development of the first installation of radar equipment on Navy combat vessels, and extensive further installations of shipboard systems for the Navy in 1940. Later he became interested in the use of radar for air safety and navigation. He led in the development of the first pulse radar apparatus flown in the United States. The apparatus was tested in an old Ford trimotor plane over the Philadelphia area during 1938 and 1939. This work led to the design of a practical altimeter employing radar principles used in military aircraft and assault Drones during World War II, and in automatic homing equipment for guided missiles. Subsequently, Dr. Wolff contributed basically to the development of a large-scale system known as Teleran, employing a combination of radar and television techniques to solve many problems of air traffic control and navigation.

The Cresson Medal, which he will receive, was founded in 1848 by Elliott Cresson of Philadelphia. It is awarded annually by the Institute to one or more persons for discovery or original research adding to the sum of human knowledge.

Dr. Wolff was born July 6, 1894, in New York City. He was graduated from Dartmouth College in 1916, and received the Ph.D. degree from Cornell University in 1923. Following his graduation from

(Continued on page 88A)

Simpson's New VOM

featuring . . .

1½% Accuracy

Excellent Repeatability

Predictable Accuracy

over wide temperature range

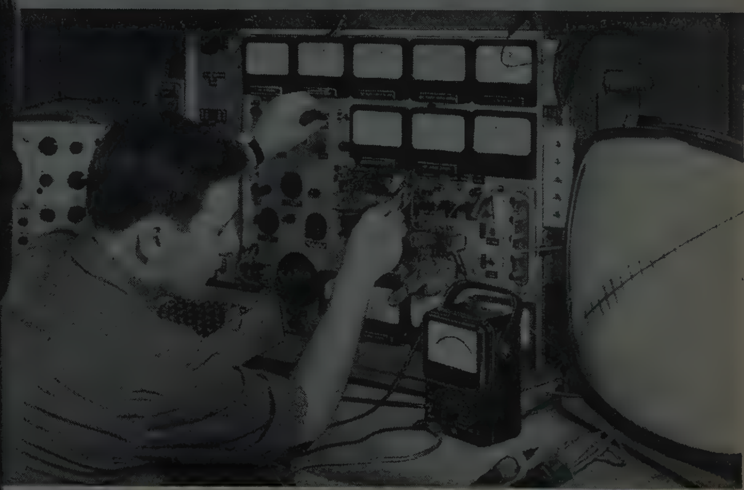


Photo courtesy of Admiral Corp. Engineer shown is using the Model 270 in evaluating operating characteristics of developmental type deflection tube.

Model 270

AC-DC VOLT-OHM-MILLIAMMETER

- MIRROR SCALE
- ½% RESISTORS
- GOLD BONDED DIODES
- FAMOUS "STAY ACCURATE" MOVEMENT
- POLARITY SWITCH

Do you need to check day-to-day variations in circuit operation? Or know what accuracy you're getting at different temperatures? If so, you especially will appreciate the capabilities of this new volt-ohm-milliammeter. For example, any particular voltage value will give identical readings today, next week, next month at an accuracy you can pinpoint from 67° to 87° F. The 270 is an engineer's VOM. Its base accuracy of 1½% DC (77°F, at full scale) covers a wide range of critical checks. It is portable, self-powered, built to have the rugged dependability typical of all Simpson VOMs. Accessories include carrying case and a variety of probes. Look it over at your Electronic Parts Distributor soon.

DC Voltage (20,000 ohms-per-volt): 0-250 mv; 0-2.5 v; 0-10 v; 0-50 v; 0-250 v; 0-1000 v; 0-5000 v. (Accuracy, 1½%)
AC Voltage (5000 ohms-per-volt): 0-2.5 v; 0-10 v; 0-50 v; 0-250 v; 0-1000 v; 0-5000 v. (Accuracy, 2%)
AF Output Voltage (With .1 microfarad internal series capacitor): 0-2.5 v; 0-10 v; 0-50 v; 0-250 v.
Volume Level in Decibels (Zero DB equal to 1 milliwatt across a 600-ohm line): −20 to +10 DB; −8 to +22 DB; +6 to +36 DB; +20 to +50 DB.
DC Resistance: 0-2000 ohms (12 ohms center); 0-200,000 ohms (1200 ohms center); 0-20 megohms (120,000 ohms center).
Direct Current: 0-50 mu a; 0-1 ma; 0-10 ma; 0-100 ma; 0-500 ma; 0-10 amp.
Model 270, complete with test leads and Operator's Manual . . . . **59^{95}**

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WORLD'S LARGEST MANUFACTURER OF ELECTRONIC TEST EQUIPMENT

IRE People

(Continued from page 86A)

Dartmouth, he served as an instructor of physics at Iowa State College and at Cornell, where he became a Hechscher Research Fellow in 1924.

He joined RCA in 1924 as a staff member of the Technical and Test Laboratory at Van Cortlandt Park in New York. In the early 1930's, he was transferred to Camden, N. J. Shortly after the end of the Second World War, he was appointed Director of the Radio Tube Research Laboratory of RCA Laboratories at Princeton, N. J. In 1951, he was appointed Director of Research, RCA Laboratories, and in 1954 he was elected Vice-President, Research.

He has received several honors for his fundamental contributions to modern radar. In 1948, he was awarded the Distinguished Public Service Award, the highest honor that can be bestowed upon a civilian by the U. S. Navy.

Long active in professional and educational affairs, he is a Fellow of the American Physical Society, the Acoustic Society of America, and the American Association for the Advancement of Science. He is a member of two honorary professional societies, Sigma Xi and Phi Kappa Phi.

He has served as an expert advisor to educational, governmental and scientific organizations. He is a member of the Advisory Committee to the Department of Physics of Princeton University, a consultant in electrical engineering to Manhattan College and a member of the Scientific Advisory Committee for the Association of Applied Solar Energy. From 1946 to 1952, he was a member of the Panel on Electron Tubes, Research and Development Board, Department of Defense.

❖

Telechrome Mfg. Corp. has appointed **Raymond F. Wulfe** (S'51–A'52–M'56) as Director of its new Southwestern Engineering Division Office in Dallas, Tex., which will be responsible for field engineering matters in Texas, New Mexico, Colorado, Wyoming, Oklahoma, Arkansas, Louisiana and Kansas.

R. F. WULFE

He was formerly with Douglas Aircraft Company in Santa Monica, Calif., where he was responsible for instrumentation systems design and worked on test planning and evaluation for the Thor IRBM weapons system. He has also worked in the heavy military electronics department of GE and with the Sandia Corporation in Albuquerque, N. M., where he was involved in special instrumentation of fission and fusion weapons testing.

(Continued on page 90A)

VT2
VT2N

VT2E

VT2F

Popular, small Model VT2 (with overvoltage). Volts output: 0-120/132; amps output: 1.5 . . . Model VT2N (without overvoltage). Volts output: 0-120; amps output: 1.8. This model delivers more current than existing transformers of comparable size and price.

VT4
VT4N

VT4E

VT4F

Models VT4 and VT4N provide output capacity greater than other units of comparable size and price. Model VT4 (with overvoltage). Volts output: 0-120/140; amps output 3.5 . . . Model VT4N (without overvoltage). Volts output: 0-120; amps output: 4.75.

OHMITE®

VARIABLE TRANSFORMERS

Complete Line Now Available from Stock

VT8
VT8N

VT8E

VT8F

VT8G

Models VT8 and VT8N offer the heavy capacity demanded for general laboratory and industrial applications. Model VT8 (with overvoltage). Volts output: 0-120/140; amps output: 7.5 . . . Model VT8N (without overvoltage). Volts output: 0-120; amps output 10.0. Units available for 240-volt input also.

Now you can get *fast delivery from stock* on 35 different models of Ohmite variable transformers. This newly expanded selection covers a high percentage of industrial needs. In it you will find single and three-phase units, two and three-in-tandem assemblies (not shown above), plus a variety of other cased and uncased models.

Ohmite "v.t." variable transformers combine fresh thinking in design with traditional Ohmite quality. For example, positive current transfer is achieved with direct brush to slip-ring, pig-tailed connection. Adjustable shafts on sizes VT4 and VT8 extend either to the brush or the base side. These two models also are *interchangeable* with competitive makes of comparable ratings. The "N" types in all three models provide additional current without overvoltage. The next time you need variable transformers, select from the line with advanced design—Ohmite.

Write for NEW Stock Catalog 30.

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RHEOSTATS RESISTORS RELAYS
TAP SWITCHES TANTALUM CAPACITORS DIODES
VARIABLE TRANSFORMERS R. F. CHOKES

IRE People

(Continued from page 88A)

Mr. Wulfe received the B.S.E.E. degree from the University of Minnesota and is lifetime member of Tau Beta Pi, and Eta Kappa Nu. He served four years with the U. S. Navy.

❖

Robert York (S'56–M'57) has joined the technical staff of Ramo-Wooldridge, a division of Thompson Ramo Wooldridge Inc. He will be attached to the Engineering division.

His background includes six years of experience in systems integration, missile test equipment and communication equipment design and nuclear instrumentation. He was formerly engaged in missile test equipment design at Douglas Aircraft Company.

He received the Bachelor's and Master's degrees in electronics from Purdue University in 1952 and 1956.

❖

James L. West (A'47–M'55–SM'55) has been promoted to the position of Director of Link Aviation's Binghamton Laboratory. In this capacity he will direct the activities of departments engaged in the development of circuits and systems for Link flight simulators, as well as components, circuits, and systems for industrial control applications. He joined Link Aviation as a Senior Electronic Development Engineer in 1952, and was successively project engineer, Manager of Analog Computer Development, and most recently Assistant Director of the Binghamton Laboratory. Prior to joining Link Aviation, he was an instructor in electronics in the Department of Electrical Engineering at Columbia University.

J. L. West

He holds the B.S. degree in electrical engineering from College of the City of New York and the M.S. degree in electrical engineering from Columbia University. He was the Chairman of the IRE Binghamton, N. Y. Chapter of the Professional Group on Electronic Computers.

❖

Robert K. Whitford (S'54–M'56) has recently been appointed associate manager of the Controls and Simulation Department, Electromechanical Laboratory, Research and Development Division, Space Technology Laboratories, Inc.

Dr. Whitford received the B.S. in 1952, the M.S. in 1953, and the Ph.D. in 1955, in electrical engineering, at Purdue University. For two years, he was a teaching assistant in Purdue's School of Engineering and a laboratory research assistant, working in network synthesis techniques.

(Continued on page 94A)

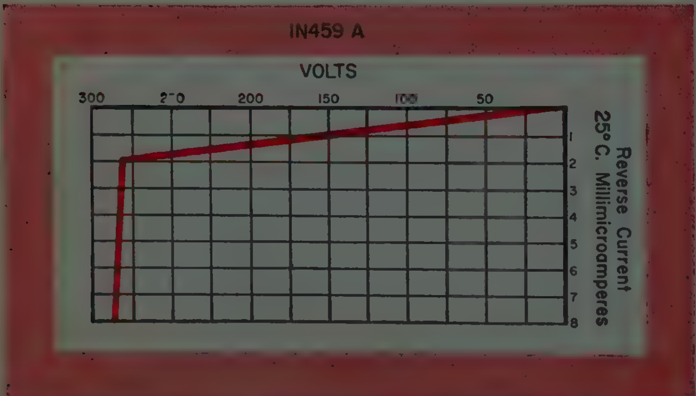
MORE DIODE per dollar

—from SYLVANIA

In Silicon Junction, Gold Bonded, and Germanium Point Contact types, Sylvania's complete mechanization assures EXTRA diode uniformity and quality control—at no extra cost.

Sylvania provides the design engineer with assurance of top-grade performance for its entire diode line. All Sylvania diodes in solder-sealed or all-glass packages are 100% tested for hermetic seals to assure maximum protection and reliability in any application—and particularly those where operating conditions are most severe.

Sylvania Silicon Junction Diodes are 100% tested on curve tracers for reverse characteristics—to eliminate such undesirable factors as soft breakdown, drift, flutter and creep.



Reverse characteristics of typical Sylvania Silicon Junction Diodes

A significant Sylvania EXTRA in automated diode quality control is the Sylvania-designed Digital Automatic Tester and Classifier. Here each unit is subjected to as many as 16 separate tests that can be programmed for an almost infinite variety of electrical characteristics. Accuracy of the automatic tester has proved to be better than 0.5 percent for every test.

In addition to 100% testing programs, all Sylvania diodes, through scientific sampling procedures, are thoroughly tested as follows:

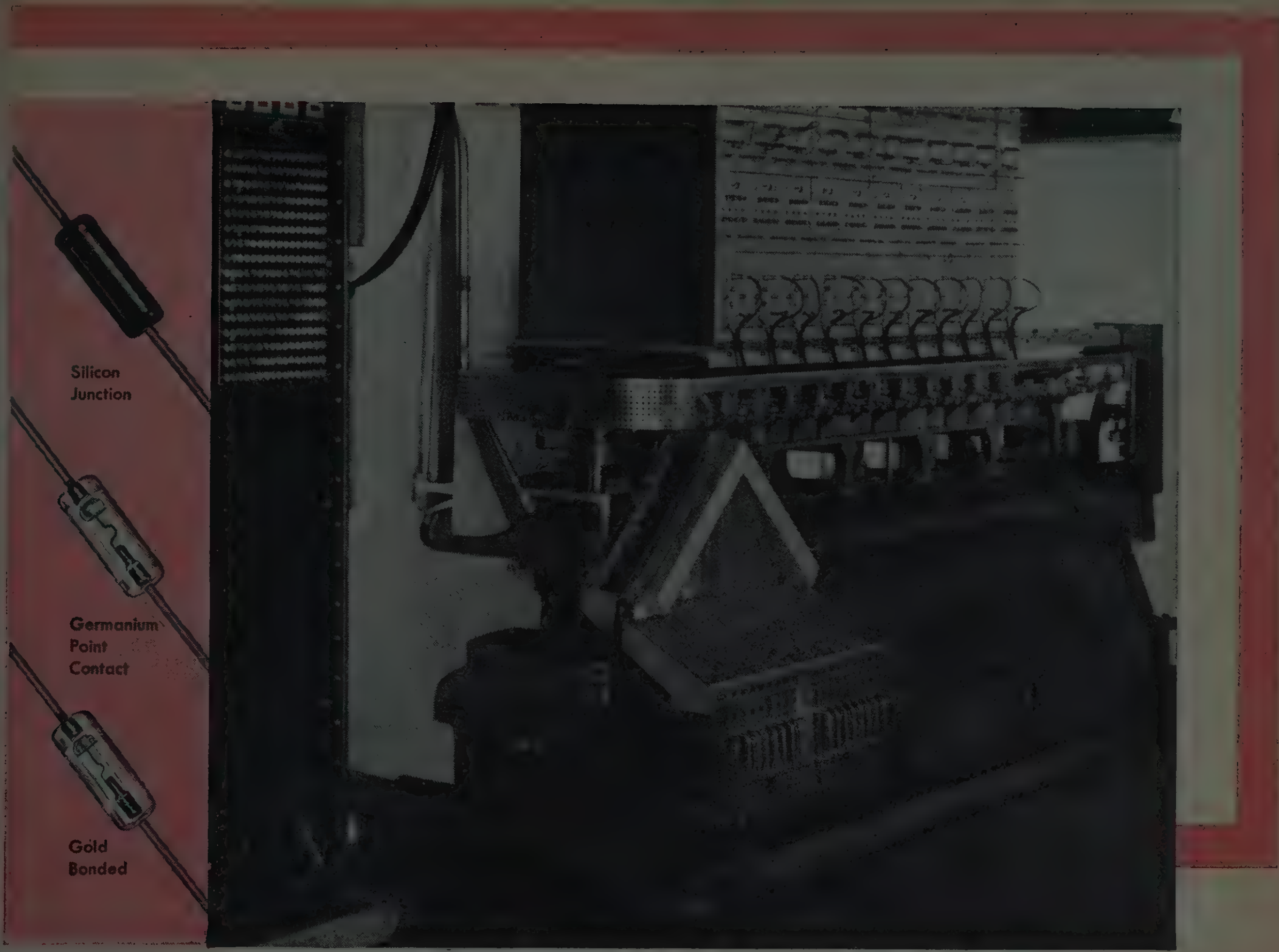
Extended Storage and Operating Life Tests—offer an extra safety factor, as they go beyond customer specifications.

Temperature Cycling Tests—ranging from —65° C to 200° C.

Lead Fatigue Tests—assurance of optimum mechanical stability.

Thermal Shock Tests—assure rugged seals.

All of these mechanical and environmental tests are made in accordance with the most stringent specification procedures—military and non-military. In some cases, such as temperature cycling, the Sylvania limits exceed those of the specification.



Sylvania's Digital Automatic Tester and Classifier—performs up to 16 separate tests for each diode unit.

For the complete story on Sylvania Silicon Junction, Gold Bonded and Point Contact diodes, contact your Sylvania representative, or write the factory directly at the address below for a free copy of the new Sylvania 16-page diode booklet.

Write for your free copy of this new 16-page Sylvania Diode booklet.

POPULAR SYLVANIA MORE-DIODE-PER-DOLLAR TYPES

SILICON JUNCTION				POINT CONTACT		GOLD BONDED	
1N456,A	1N461,A	1N482,A,B	1N486,A,B,	1N126A	1N191	1N270	1N283
1N457,A	1N462,A	1N483,A,B	1N487,A	1N127A	1N192	1N276	D1165
1N458,A	1N463,A	1N484,A,B	1N488,A	1N128	1N198	1N279	D1248
1N459,A	1N464,A	1N485,A,B				1N281	

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Industrial Engineering Notes*

Military Electronics

Development of a new ultra-sensitive frontline radar which can look deep into hostile territory and detect the slightest enemy ground movement was announced today by the Department of the Army. The set will spot a rolling tank, truck, or jeep at ten miles, or a soldier crawling on the ground two miles away. It can detect the soldier if any part of his body moves more than one mile an hour. These are average distances over typical battle terrain. In one test, under ideal conditions, the set spotted a soldier walking 15 miles away. Each type of target produces a characteristic sound in the radar. An experienced operator can distinguish the sound made by a walking soldier, the two-toned whistle of a tank, the steady whine of a truck or jeep, a chorus of sounds created by a patrol of soldiers, and the pulsating rumble indicating soldiers in marching formation. In addition to the sounds, the operator can watch the set's radarscope to get more precise information on a target's position and direction of movement. The radar is part of an over-all program under direction of the U. S. Combat Surveillance Agency and was developed jointly by the U. S. Army Signal Research and Development Laboratory at Fort Monmouth, New Jersey, and the Hazeltine Corporation of Little Neck, New York.

Governmental and Legislative

Rep. Oren Harris (D., Ark.), Chairman of the House Commerce Committee, last week introduced a bill (H.R. 8426) to create a new independent agency to allocate radio frequencies as between government uses and non-government uses. The new agency, to be known as the Frequency Allocation Board, would consist of three members to be appointed by the President from civilian life, subject to Senate confirmation, for terms of nine years. . . . **In addition to the creation of a 3-man Board, the bill would create in the Executive Office of the President a new position of Government Frequency Administrator to be appointed by the President and to serve at his pleasure.** The administrator's function would be to assign, on behalf of the President, radio frequencies to federal government departments and agencies, and to keep a check on the efficient utilization of the frequencies thus assigned. The bill also would safeguard the President's powers with regard to the radio spectrum in any questions or situations involving the national security or foreign relations. It would continue in effect the authority and responsibilities of the FCC to allocate and assign radio frequencies to non-federal government users. The new FAB and the President would be given authority to modify or cancel allocations of radio frequencies presently allocated for non-federal government uses or for government uses, respectively. However, where such frequencies have been used regularly and extensively for the purposes for which they were allocated, and large sums have been invested in equipment especially designed for use of such frequencies, the Board or the President would not be expected to modify or cancel such allocations, unless such action was determined to be necessary in the interest of national security. . . . **Mr. Harris stated that his Committee recently conducted a two-day panel discussion—on June 8 and 9—in which top-flight experts from industry (including EIA), universities, and the government participated.** The overwhelming majority in the discussion expressed the view that a rational government program for spectrum allocation as between Federal Government uses and non-Federal uses was urgently needed to meet the consistently increasing demand for spectrum space by both groups. . . . **The FCC last week adopted a report and order concluding its investigative review of microwave and other frequency allocation problems above 890 mc, and terminated the fact-finding proceeding in Docket 11866 which began November 8, 1956 to obtain information concerning service allocation needs in that part of the radio spectrum in light of microwave and other developments since the last detailed review was made more than 14 years ago.** The FCC said the record supports the following two

(Continued on page 96A)

* The data on which these Notes are based were selected by permission from *Weekly Reports*, issue of August 3, published by the Electronic Industries Association whose helpfulness is gratefully acknowledged.

IRE People

(Continued from page 90A)

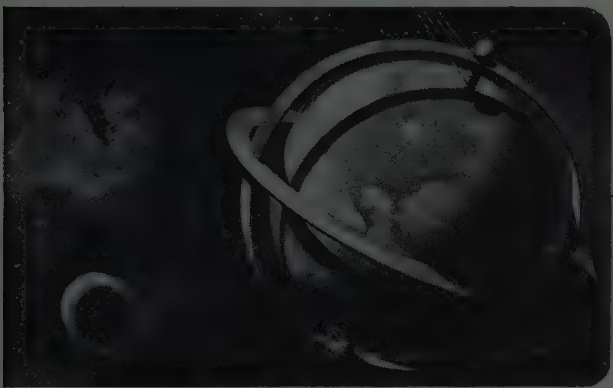
He joined Space Technology Laboratories in 1955 and is now a member of the Senior Staff. He has had over seven years of experience in servomechanisms, communications and missile control systems.

Dr. Whitford is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu, and was awarded an RCA Predoctoral Fellowship in Electronics by the National Research Council. He is also a member of the American Institute of Electrical Engineers.

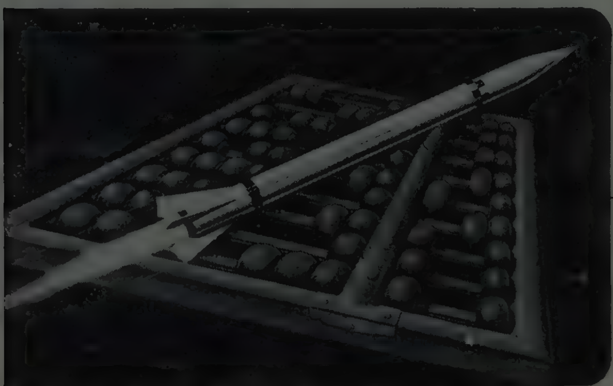
❖

Pioneering Achievements in Electronics at JPL

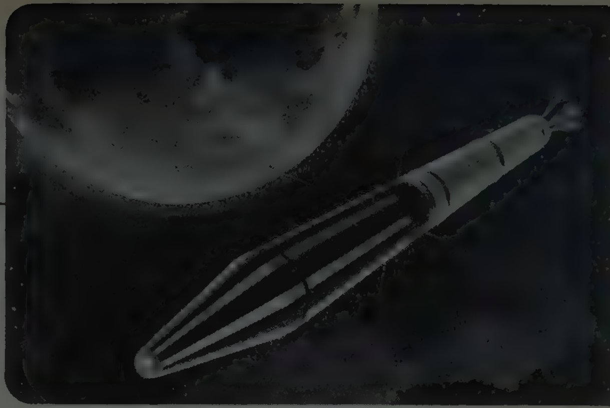
GUIDANCE RESEARCH . . . by JPL has led and advanced the field of missile guidance. Among these achievements are the application of Wiener RMS methods to multiple-input, multiple-loop servos, and matching missile trajectory to missile control transfer function for optimum accuracy.



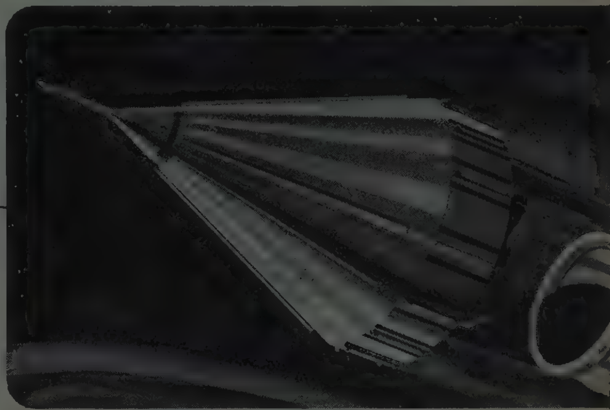
GUIDANCE SYSTEMS . . . both inertial and radio-command types employing new concepts of radar communication have been pioneered at JPL. This guidance system development activity is supported by basic research in all phases of electronics.



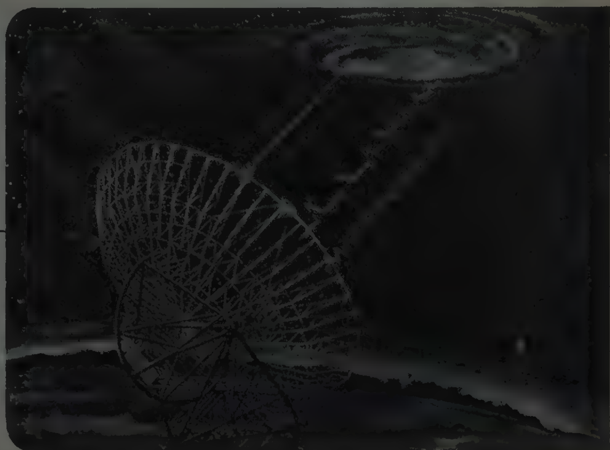
COMPUTERS . . . and the application of computing techniques to missile guidance systems have been pioneered by JPL. The Laboratory is now searching for new techniques that will further advance the state of the art in digital guidance components and computer systems.



DATA TRANSMISSION . . . brings news from space via the Explorer series. Explorer III used a tape recorder the size of a cigarette pack capable of transmitting two hours of information in 5 seconds. Electronic payload weight was approximately 11 lbs.



INSTRUMENTATION . . . of the moon probe provided measurement of radiation environment at distances far from the earth. Telemetered data revealed the existence of high intensity radiation. Miniaturization resulted in an instrument payload weighing only 10 lbs.



COMMUNICATIONS . . . pioneering in interplanetary communications resulted in this giant parabolic radio antenna, 85 feet in diameter, developed by the Laboratory which enables the tracking and reception of scientific data from great distances.

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Industrial Engineering Notes

(Continued from page 94A)

conclusions: (1) there are now available adequate frequencies above 890 mc to take care of present and reasonably foreseeable future needs of both common carriers and private users for point-to-point communications systems, and (2) there is no basis for generally concluding that the licensing of private communications systems would adversely affect, to any substantial degree, the ability of common carriers to provide service to the general public or adversely affect the users of such common carrier service—therefore, unnecessary to consider whether such licensing is contrary to the public interest. The FCC emphasized, however, that it has not determined that there are unlimited frequencies available or that future conditions may not require that limitations and restrictions be placed upon such authorizations and operations. It was further stated that the FCC proposes to watch this matter very carefully and, if future conditions so indicate, to take whatever corrective action may be deemed appropriate at that time. . . . **The FCC last week invited comments to a notice of proposed rule making looking toward adopting interim technical standards to govern the granting of applications for private communications systems (excluding broadcasters) using microwave frequencies above 952 mc.** This is the first rule-making proposal stemming from the report of the commission on 890 mc and above (see preceding story), which among other things, looks toward the authorization of private point-to-point communications systems on a more liberalized basis than has heretofore been the case. The adoption of the proposed technical standards would result in applying orderly technical criteria to the issuance of microwave authorizations for such private microwave systems until rules and standards are adopted for the use of microwave frequencies on a regular basis in each of the respective Safety and Special Radio Services. . . . **The FCC last week announced that it and the Office of Civil and Defense Mobilization have issued a progress report on the joint venture of looking toward an improved overall pattern of frequency allocations which could be implemented within the next 10 to 15 years.** The report states that the technical group engaged in the program have reached agreement on the terms of reference and taken actions which include the following:

1) Invited the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards to name a representative to participate in the work of the technical group, in view of the necessity for basing future allocation planning on the most accurate propagation data currently available.
2) Requested the CRPL to prepare graphical presentations of necessary power versus distance for various

(Continued on page 98A)

Industrial Engineering Notes

(Continued from page 96A)

emissions, data rates, antenna heights and megacycle orders of frequency.

3) Agreed as a first step in the over-all program to deal with the band 50–1000 mc on the ground that it represented the knottiest problems.
4) Requested the CRPL to concentrate its efforts initially on the band 50–1000 mc, setting August 1, 1959 as the target date for a report thereon.
5) Agreed to treat at least the broadcasting, land mobile, aeronautical mobile, maritime mobile, radiopositioning, radionavigation, and earth-space services in its consideration of the band 50–1000 mc.
6) Requested the Government agencies to present to the technical group their present or foreseeably unfulfilled frequency requirements for the band 50–1000 mc, of which they were aware, not later than August 1, 1959. Having but recently completed taking testimony in its Docket No. 11997 dealing with the band 25–890 mc, the Commission is in a particularly good position to supply such information with respect to non-government requirements.

Industry Marketing Data

EIA figures released last week show great gains in both radio and TV output in June compared with May and June of last year. The figures also show substantial increases for both types of receivers during the first half of the year compared with the like six-months period in 1958. Television output in June totaled 571,003, including 29,064 with UHF tuners, compared with 431,911 TVs made in May, including 28,247 sets capable of receiving UHF signals, and 337,090 television sets made in June last year, which included 36,811 with UHF tuners. Cumulative TV output during the first half of this year totaled 2,782,715 receivers including 180,443 with UHF tuners, compared with 2,167,930 TVs made during the like six-months period last year, which included 209,726 UHF receivers. **Radio makers produced 1,430,165 receivers, including 637,806 auto sets in June compared with 1,039,562 radios made in May including 476,222 auto sets, and 742,426 radios made in June last year including 235,433 auto receivers.** Cumulative output during the first half of this year totaled 7,107,586 including 2,900,196 automobile radios compared with 4,619,163 radios made at this same time last year which included 1,464,519 auto radios. The number of FM radios made in June totaled 50,783 compared with 48,841 in May and 31,425 in April. Cumulative output of FM radios totals 223,423 during the first six months of this year. There is no comparison for June and year-to-date in 1958 since EIA only last July began its FM radio output compilation.

This man is using the industry's most advanced swept microwave oscillator

now available from ALFRED ELECTRONICS

No other sweeping oscillators offer as many solid advantages as Alfred Electronics' new series 620 models, built by the industry's leading manufacturer of high quality, broadband microwave instruments. Note these features:

★ **Six models, covering 1 to 18 kmc.** Broadest frequency range available. Electronic sweep of RF output, or extremely stable CW operation.

★ **Linear frequency sweep coverage** over all or part of each band for rapid evaluation of reflection coefficient, gain, attenuation and other network transfer characteristics.

★ **Two adjustable frequency markers** for convenient calibration of oscilloscopes or recorders. Markers save valuable test time by indicating either band limits or intermediate frequency values. An exclusive Alfred feature on all models.

★ **0.5 microseconds rise and fall** response to AM—equivalent to a 2 megacycle band pass. Another exclusive Alfred feature.

★ **Quick Look readout.** See frequency range, markers and sweep time at a glance. No cumbersome calculating.

★ **Fast sweep** for flicker-free oscilloscope presentation; slow sweep for mechanical recorder operation.

Using Alfred Model 623 Microwave Oscillator (left) to test small signal and saturation gain of Model 503 Traveling Wave Tube Amplifier. Microwave Leveler, Alfred Model 704, holds power output from oscillator constant within ±1 db.

BRIEF SPECIFICATIONS

Model	621	622	623	626	624	625
Frequency Range (kmc)	1-2	2-4	4-8	6.5-11.5	8-12.4	12.4-18
RF Output Connector	"N" Female	"N" Female	"N" Female	"N" Female	"N" Female	"P" Band Cover Flange UG/419/U
Prices	$3090	$2990	$2890	$2990	$2890	$3450

GENERAL

FREQUENCY CONTROL: Continuously adjustable with direct calibrated dial. Calibration accuracy, 1%.

POWER OUTPUT (minimum): 10 mw. Continuously adjustable from zero to maximum.

VSWR (maximum): 2:1.

SWEEP

SELECTOR: Recurrent sweep, single sweep, CW, and external on panel switch.

CONTROL: Single sweep, triggered by panel button, or external positive going signal 20 volts or greater.

SWEEP WIDTH: Continuously adjustable from 0 to any part of entire frequency range.

TIME: 100 to .01 seconds.

MONITOR OUTPUT: Positive linear sawtooth, 45 volts peak; Blanking out, 75 volts negative.

EXTERNAL SWEEP: 200 volts gives full sweep width.

AMPLITUDE MODULATION

INTERNAL SQUARE WAVE: RF output alternately 0 and unmodulated CW value. Frequency 800 to 1200 cps.

EXTERNAL: 30 volts maximum signal increases RF output from 0 to maximum.

POWER INPUT: 105 to 125 volts; 60 cps.

Write us for complete details of these new oscillators. We'll also send you our new short form catalog, which describes Alfred's complete line of packaged traveling wave tube amplifiers.

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PALO ALTO, CALIFORNIA

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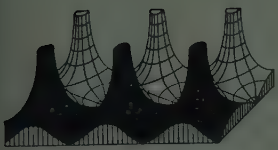
October, 1959
Vol. 47 No. 10

Proceedings of the IRE

Poles and Zeros



WESCON. If one likes sun in his summer, then San Francisco during WESCON is not to be recommended. However, if one is willing to accept continual air conditioning, the avoidance of showers, the inevitability of good San Francisco food, the hospitality and friendliness of the natives and recent immigrants, and a fine exhibit and technical program, then San Francisco during WESCON is the place to be. A product of fertile minds and expert management, this year's colossus of the West set high marks in every regard.

The technical program employed the experimental method with good results. The restriction of all sessions to three papers undoubtedly led to a low percentage of acceptances, and thus to higher quality in the technical program. This minimization of the acceptance/submission ratio as a criterion of quality, if it needed more than heuristic support, was amply proved by perusal of the abstracts and a sampling of the technical sessions. The limitation to three papers per two and one-half hour session also permitted ample coverage by the author as well as discussion from the floor. A novel feature of the discussion was the employment of the phenomenon of catalysis through a designated panel of discussers, these to present those first comments and questions which are so difficult to obtain unless planned in advance by an astute meeting chairman. Thus the audience was easily led into a form of bull session, and it was pointed out that this was indeed appropriate to the locale of the Cow Palace.

The exhibit areas were well arranged, even with aisles, although the configuration of the buildings tended to place the visitor in repetitive orbit—a device for precessing the orbit is needed. The breadth of the West Coast electronics industry, as well as of the whole field, was amply demonstrated once more; we were particularly impressed with the number of exhibits, not in themselves electronic, which represented products or processes being supplied to the industry.

Among our more useless conclusions from the show we find the following: vacuum tubes are still manufactured; do not develop a computer for an abstruse purpose—the high school boys already have it, as shown in the Future Engineers Show; modern equipment will not work without a projecting rim around the panel; stacking is important, be it component, molecular, or blonde; reliability is not optimum in the microphone-to-loud speaker link; electrons are still green.

SQ. These letters represent one of the less-well-known activities of the IRE, namely the STUDENT QUARTERLY, published for the benefit and edification of our Student Members in the colleges and the technical institutes. The fall issue, just available, is more than representative of the manner in which the electronic science story is carried to the students. The story of the discovery of the Van Allen radiation belts by Van Allen, the why of research by Terman, an analysis of the electronic field by McFarlan, are only a few of the papers presented during a typical year of this publication. The technical bits of information are sidebands on a carrier of cheery, informal, and sometimes surprising style—with cartoons, yet. Only the electronic profession could provide the bandwidth for this publication.

It has been stated that we must expand our knowledge by six per cent per year just to keep up with scientific inflation, and SQ is an attempt to bring up our potential engineers in the way they should go. Yes, you too, can subscribe; aren't you still a student?

Space ad Infinitum. We have always had some slight doubt over the manner in which nature will accept the infinity implied by Einstein in his various relations which employ the factor $(1-v^2/c^2)^{-1/2}$. Noting that some of our classical ideas failed when we tackled micro-micro-space within the atom leads us to wonder if some of our other ideas may fall apart when we approach macro-macro-space among the stars. The publication in the June PROCEEDINGS of the paper "Relativity and Space Travel," by J. R. Pierce, has raised questions from many others if our correspondence is an indication. To present the arguments to all, we have selected four letters typical of the many, and they appear on pages 1778–1780, along with Dr. Pierce's reply.

With Mechta, Pioneer IV, and proposed satellite clock experiments, perhaps infinity is closer than we think.

Law of the Land. A set of By-Laws, by which our new Constitution is implemented, went into effect on August 19, by Board of Directors action of the preceding day. As we have previously pointed out, adoption of these new By-Laws is largely intended to continue present policies in IRE government. One change of import to all will soon be apparent, when you receive your annual ballot. This will call for a vote for two vice-presidents instead of the usual one. There will be a North-American Vice-President to actively aid the President, and a Vice-President not from North America, to emphasize that IRE is indeed an international organization.

Publication of the complete By-Laws will follow at an early date.—J.D.R.

Harry F. Olson

Director, 1959–1960

Harry F. Olson (A'37–VA'39–SM'48–F'49) was born on December 28, 1902 in Mt. Pleasant, Iowa. He received the degrees of B.E. in 1924, M.S. in 1925, Ph.D. in 1928, and Professional E.E. in 1932, all from the University of Iowa. In 1928 he joined the Radio Corporation of America, and worked in several of their divisions until 1941, when he joined the RCA Laboratories in Princeton, N. J. He is presently the Director of the Acoustical and Electromechanical Laboratory of the RCA Labs.

One of Dr. Olson's early contributions during his career with RCA was the velocity microphone, the first microphone with uniform directivity, which became standard for broadcasting use. Subsequently, he pioneered in several other directional types of microphones, including the unidirectional types now used in television broadcasting and sound motion picture filming. During World War II he developed underwater sound equipment, anti-noise microphones and high power announce systems. He also has made pioneering contributions to loudspeaker development, including the duocone speaker for high fidelity sound reproduction, and to the development and improvement of phonograph pickups and disc recording equipment, sound motion picture and public address systems. In addition, he has guided and contributed substantially to the development of electronic noise reducers, stereophonic sound systems, magnetic tape recorders for sound and television, the electronic music synthesizer, and the phonetic typewriter.

Dr. Olson holds over 80 U. S. Patents on devices and systems in the acoustical field and is author of over 85 articles and papers published in professional journals as well as the books "Elements of Acoustical Engineering," "Acoustical Engineering," "Dynamical Analogies," and "Musical Engineering." From 1939–1943 he was a lecturer in acoustical engineering at Columbia University, New York, N. Y.

For his contributions to the field of audio engineering, Dr. Olson received the Modern Pioneer Award of the National Association of Manufacturers in 1940, the John H. Potts Medal of the Audio Engineering Society in 1952, the Samuel Warner Medal of the Society of Motion Picture and Television Engineers in 1955, the John Scott Medal of the City of Philadelphia in 1956, and the Achievement Award of the IRE Professional Group on Audio in 1956. In April of this year he was honored by election to the National Academy of Sciences.

Dr. Olson's affiliations include membership in Tau Beta Pi and Sigma Xi. He is a Fellow of the American Physical Society, the Acoustical Society of America, the Audio Engineering Society, and the Society of Motion Picture and Television Engineers. He was president of the Acoustical Society of America in 1952.

His IRE activities have included membership on several Institute committees including Annual Review, Board of Editors, Editorial Reviewers, Electroacoustics, Papers Procurement, and Standards. He has been IRE representative on several ASA committees. In 1957–1958 he served as chairman of the Professional Group on Audio.

Scanning the Issue

The Magnesium Oxide Cold Cathode and Its Application in Vacuum Tubes (Skellet, *et al.*, p. 1704)—Earlier this year a great deal of publicity appeared in the newspapers about a new type of cathode which would operate cold, without requiring the usual heater filament to induce electron emission. The absence of a heater in a tube eliminates one cause of power consumption; and by operating the cathode cold, the gradual depletion of cathode chemicals by evaporation is avoided, suggesting a long operating life. These features and the widespread publicity given them have aroused a great deal of interest in the tube industry. The technical details of this novel development are now reported. The cathode consists of a very thin layer of magnesium oxide on a nickel base. During operation, avalanche multiplication of electrons occurs within the magnesium oxide layer and a potential of about 150 volts, with respect to the base, develops on the outer surface of the layer, propelling the electrons with sufficient velocity to escape from the surface. This paper is most welcome: it is excellently written, it provides a clear description of both the capabilities and limitations (*e.g.*, noise) of a new device, and in so doing gives a more complete and accurate picture than was provided by the popular press.

The Quadrupole Amplifier, A Low-Noise Parametric Device (Adler, *et al.*, p. 1713)—Among the several kinds of parametric amplifying devices being talked about a great deal these days, one of the most interesting is a class that employs an electron beam. This class differs from conventional beam-type tubes, such as traveling-wave tubes, in that the fast electron wave of the beam, rather than the slow wave, is utilized for amplifying the signal. This distinction is important because noise present in the beam when it leaves the gun can never be completely removed from the slow wave, while it can, in theory, from the fast wave. The inherently noisier slow wave has been used in conventional devices because, until recently, no way had been found to amplify the fast wave. About two years ago, however, it was recognized that the fast wave could indeed be amplified by adding to the system an additional power source which operated on the fast wave at a pumping frequency higher than the signal frequency—in short, by applying the principle of parametric amplification. This idea was subsequently applied successfully to amplifying the fast space-charge wave of an electron beam. In this paper, it is applied to another type of fast wave, the cyclotron wave, *i.e.*, the spiralling motion of the electrons as they proceed along the beam path. The authors have devised a four-pole (quadrupole) structure which, when connected to the pump source, produces an alternating field which enhances this signal-induced spiralling motion, thus amplifying the signal. The resulting device shows a remarkably low noise figure for an electron device, as low as 1.4 db in certain applications. It also enjoys high stable gain over fairly wide bands. This development stands as an outstanding contribution to the art of low-noise amplification, one that will be referred to frequently in the future in a number of fields. The paper has the added blessing of being written in such a lucid and interesting style that all members will enjoy and benefit from reading it, regardless of their own field of interest.

Generation of Harmonics and Subharmonics at Microwave Frequencies with *P-N* Junction Diodes (Leenov and Uhlir, p. 1724)—There is wide interest today in nonlinear devices that can be used as frequency converters to provide power sources or frequency standards in the microwave region. Resistive devices, ferrites and, most recently, a nonlinear capacitance junction diode have been employed in this role. In this paper, the author investigates the last-named item, compares it with a nonlinear resistance, and shows that the nonlinear capacitance is considerably more efficient. This higher efficiency plus the fact that a nonlinear capacitance, unlike a nonlinear resistance, can generate subharmonics as well as harmonics, gives the one a clear advantage over the other.

Comparison and Evaluation of Cesium Atomic Beam Frequency Standards (Essen, *et al.*, p. 1730)—As the first comparison between two high-class frequency standards based on similar principles but of different construction, this paper will be of substantial interest to physicists, workers in frequency control and measurement, and those concerned with navigation and missile control problems. An American cesium atomic beam frequency standard known as the Atomichron® was shipped to the National Physical Laboratory in Teddington, England, where it was compared with the NPL cesium frequency standard. The unresolved discrepancy between the standards was found to be about 2 parts in 10^{10}. One important aspect of this comparison is that it provides information that will help in determining the accuracy with which such comparisons can be made on an intercontinental scale by means of transatlantic radio transmissions—a measurement program that is now in progress between NPL and Harvard.

Pattern Detection and Recognition (Unger, p. 1737)—Unfortunately, humans and data-processing machines do not speak the same language. It is usually necessary for a human operator first to translate the data into the digital language of the machine before the machine can be put to work. In some cases, the translation job would be so great as to defeat the purpose of using the machine at all. One of the most fascinating and potentially useful areas currently being investigated is in devising input devices which will do the translating automatically. This paper develops two interesting methods of automatic pattern processing, one of which was successfully used to detect L-shaped figures in the presence of other randomly drawn patterns. The other method made it possible to recognize hand-lettered numbers and letters. Identification of any character is uniquely established by asking from three to nine questions, in proper sequence, from a list of 36 questions concerning details of the shape of the pattern. It is estimated that within five years equipment could be available for performing character recognition operations at the rate of 2500 characters per second (which means this page would be gulped down in about 3 seconds).

A Unified Analysis of Range Performance of CW, Pulse, and Pulse Doppler Radar (Bussgang, *et al.*, p. 1753)—Volumes have been written on predicting the range performance of pulse radars, but relatively little regarding CW and pulse Doppler radars. This timely paper not only fills the gap but also provides a unified computational method which is especially useful in comparing two radars. It will be particularly helpful to radar engineers who do not have the inclination to wade through the more mathematical treatments of this subject.

Absorptive Filters for Microwave Harmonic Power (Met, p. 1762)—With transmitter powers in pulse radar systems rising tremendously and with increasing use of the microwave spectrum for communication purposes, the problem of harmonic interference has become very real and far reaching. This discussion of improved methods of suppressing the harmonic output transmitters should, therefore, interest a fairly wide circle of IRE readers.

Simple Methods for Computing Tropospheric and Ionospheric Refractive Effects on Radio Waves (Weisbrod and Anderson, p. 1770)—Simple, practical formulas are presented which greatly reduce the labor of computing the bending of radio waves that pass through the troposphere and ionosphere. Other refractive effects such as signal retardation, Doppler error, and Faraday rotation are also included, making this work of timely usefulness to a large group of people interested in accurately tracking radio stars, satellites, missiles, and other high-altitude objects.

Scanning the Transactions appears on page 1790.

The Magnesium Oxide Cold Cathode and Its Application in Vacuum Tubes*

A. M. SKELLETT†, FELLOW, IRE, B. G. FIRTH†, AND D. W. MAYER†

Summary—**The MgO cold cathode is a new source of electrons with possible applications in various types of electron tubes. It consists of a thin layer of porous magnesium oxide on a nickel base. A strong electric field that exists across the layer while in operation is believed to produce the electron emission from the surface. Evidence supports the theory that avalanche multiplication occurs in the layer. This cathode glows with a pale blue luminescence during operation. The velocity distribution of the emitted electrons shows a peak at 13 electron volts. The outer surface potential has been measured and found to be of the order of 150 volts with respect to the nickel base. The emission is not self-starting, and starting means are discussed. Noise, life, emission density, and temperature range of operation are discussed in so far as present knowledge permits. An experimental design of an amplifier tube employing this cathode is described and the characteristics of the tube are given.**

Introduction

THE magnesium oxide cold cathode was the result of studies of field dependent secondary emission[1-5] carried out at the Research and Development Laboratories of the U. S. Signal Corps, Evans Signal Laboratories, Fort Monmouth, N. J. Dobischek[6] completely isolated the self-sustained emission component and produced it in tubes that had no provision for bombardment by primary electrons. These tubes were simple diodes, each consisting of a nickel cathode base covered with specially prepared magnesium oxide and a positive anode located a short distance away to draw the electron emission. He tried various methods of preparation of the MgO coatings, a number of which were successful, and determined that porosity of the layer was essential for good operation. His results encouraged the belief that this new type of cathode might be used in electron tubes.

On July 1, 1956 under a Signal Corps contract, Tung-Sol Electric Research Laboratories undertook the job of developing the MgO cathode toward this end. By further research and development and by applying vacuum-tube-production techniques, reproducible cathodes of good quality have been obtained.

Preparation of the Cathode

In the early work carried out at the Signal Corps Laboratories, a number of methods were tried for producing the magnesium oxide coating. These included evaporation of magnesium through oxygen at a pressure of 80 microns, oxidation of vacuum-deposited MgO films, decomposition of $MgCO_3$ layers, and burning of magnesium in front of the cathode base metal to collect the MgO smoke. The best results were obtained with this last or "smoke" technique; the cathodes were much quieter and indicated that with further development they might be made to rival thermionic cathodes for some applications.

The original cathodes were made in the Tung-Sol Research Laboratories by two methods. The first was to spray magnesium oxide onto a magnesium or nickel base; the second was to coat the nickel sleeve by electrophoretic depostion of magnesium oxide. Both produced operative cathodes, but the sprayed cathodes showed the greater promise and the cataphoretic method was abandoned.

The cathodes are presently prepared by spraying a mixture of magnesium superoxol ($MgO+25\%$ MgO_2) and magnesium carbonate in a vehicle of amyl acetate onto a nickel base. This base is usually a typical cathode nickel sleeve made of 499 alloy roughened by sand blasting and oxidized by heating in air. The coating is approximately 35 microns thick and appears rough textured.

The cathode is then assembled in the tube structure and processed in accordance with a typical exhaust procedure. It has been found necessary to heat the cathode to 800°C. in air or oxygen at reduced pressure as part of this procedure.

Fig. 1. shows the texture of the magnesium oxide surface of a processed cathode. During the processing the carbonate breaks down with the liberation of CO and CO_2. This evolution of gas enhances the porosity. It is believed that the final coating is magnesium oxide of a

Fig. 1—Photograph of the surface of a processed magnesium oxide cathode; magnification about 100 times.

* Original manuscript received by the IRE, May 4, 1959; revised manuscript received, June 15, 1959. This investigation was sponsored by the U. S. Army Signal Res. and Dev. Laboratory.
† Res. Div., Tung-Sol Electric, Inc., Bloomfield, N. J.
1 L. Malter, *Phys. Rev.*, vol. 49, p. 478; 1936.
2 L. Malter, *Phys. Rev.*, vol. 50, p. 48; 1936.
3 H. Jacobs, "Field dependent secondary emission," *Phys. Rev.*, vol. 84, pp. 877–884; December, 1951.
4 H. Jacobs, J. Freely, and F. A. Brand, "The mechanism of field dependent secondary emission," *Phys. Rev.*, vol. 88, pp. 492–499; November, 1952.
5 D. Dobischek, H. Jacobs, and J. Freely, "The mechanism of self-sustained electron emission from magnesium oxide," *Phys. Rev.*, vol. 91, pp. 804–812; August, 1953.
6 D. Dobischek, Abstract No. 78, Meeting of Electrochem. Soc., Wash. D. C.; May 12, 1957.

high degree of purity, but there is some evidence that small amounts of impurity may play a role in the operation.

In order to understand the mechanism of operation it is necessary to know the outer surface potential of the oxide layer and the energy distribution of the emitted electrons.

Outer Surface Potential

A small cathode-ray tube was made, complete with electrostatic deflecting plates and fluorescent screen. The outer pair of deflecting plates served also as a magnesium oxide cold cathode diode. One plate was covered with the MgO porous coating prepared as described above, and the other plate served as the anode. Knowing the potential on the anode plate, the velocity of electrons in the beam, and the important distances involved, it was possible to determine the surface potential on the cathode plate from the deflection of the beam as measured on the fluorescent screen.

The tube used for this experiment consisted of a 5CP1 cathode ray electron gun sealed in a two inch OD bulb screened at one end. The last set of deflection plates was removed from the gun and replaced with 499-alloy plates 20 mm square and 4 mm apart. One plate was coated with MgO (about 1.9 mg/cm² and about 41 microns thick). The other plate was left uncoated. The distance from the center of these deflection plates to the screen was 60.8 mm (2 inches from the outer edge of the plate to the screen). The first set of deflection plates, 90 degrees from the second pair, was used to scan the electron beam vertically between the MgO cathode and plate at 60 cps. The image formed on the screen was a straight vertical line. Evidently any variations in surface potential were averaged out over the 2 cm length of the cathode. The arrangement of the electrodes and the circuit is shown in Fig. 2.

Fig. 3 shows the variation of the surface potential, curve S, determined in this way, as the current drawn from the cold cathode was increased. The anode potential for each value of current is also shown, as curve P. These curves show that the cathode surface potential, S, varied from 145 to 155 volts with respect to the cathode nickel base, as the current drawn varied from 0.1 to 0.6 ma. The anode potential, P, varied from 250 to 280 volts over this same current range. At 0.1 ma the difference of potential between S and P was 105 volts, and at 0.6 ma it was 125 volts. A number of such curves were taken with two tubes of this type, and although the currents were not as stable as might be desired, the curves all followed this general pattern.

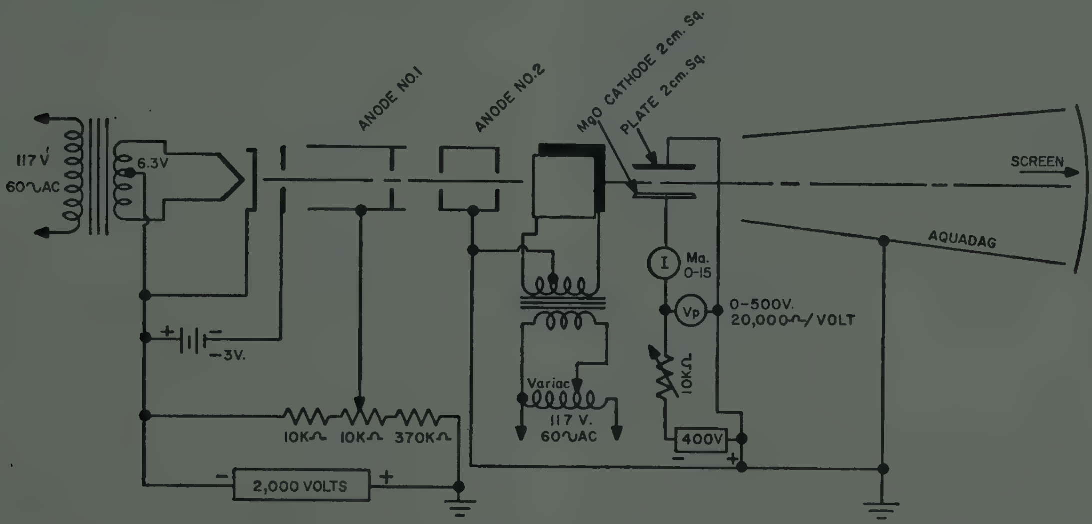


Fig. 2—Arrangement of elements and circuit for the experimental determination of surface potential.

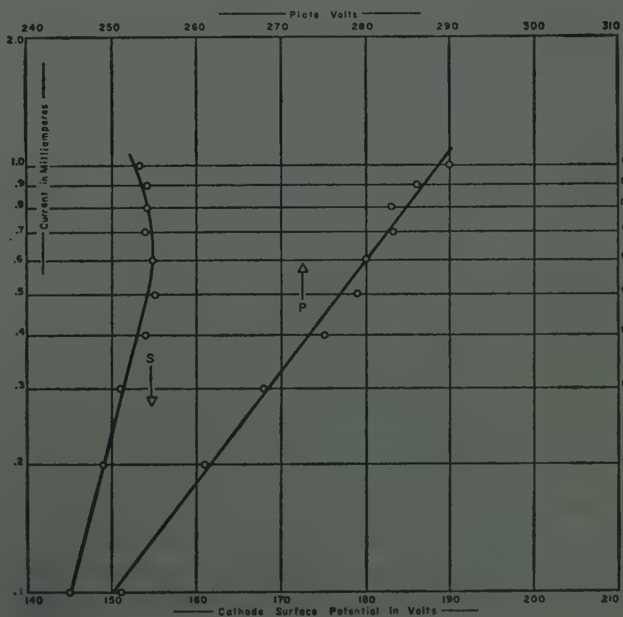


Fig. 3—Variation of surface and anode potentials with emission current.

The maximum emission density that has been drawn to date is 145 milliamperes per cm^2. However, at this value cathode cooling must be provided.

Blue Luminescence

A distinctive characteristic of this cathode is that it glows with a pale blue luminescence when operating. The brightness of this light varies with the emission intensity, thus providing a simple means of observing the uniformity of emission across the cathode surface.

The early cathodes were characterized by two types of luminescence. A general blue glow was distributed over the emitting areas, and brilliant points of light, also blue in color, were located at randomly spaced points on the cathode surface. These points were unstable and scintillated with a cycle of brightness variation that was often in the form of a saw-toothed wave. Much of the noise of the early cathodes was traced to these scintillating points, and effort was directed toward their elimination. This has been accomplished, and present cathodes have a uniform steady glow when viewed macroscopically.

Theory of Operation

In attempting to explain the mechanism of field-dependent secondary emission from porous magnesium oxide, Jacobs, Freely and Brand[4] postulated an avalanche effect patterned after that in a Townsend discharge in gas. Dobischek, Jacobs and Freely[5] carried this theory further and found that it applied to the emission from the magnesium oxide cold cathode. This cold cathode is of course identical with the porous MgO layers of the secondary emission studies.

The fundamental expression for the Townsend avalanche discharge is

$$I = I_0 e^{\alpha x} \tag{4}$$

where I is the total current, I_0 is the initial current, x is the distance through which the discharge takes place, and α is the number of new electrons created per unit length. Since the relationship between the distance and the voltage in the case of the MgO layer may be assumed to be linear, we may substitute BV for αx, where B is a constant and V is the voltage. Eq. (4) then becomes the same as (3), which was obtained from the experimental data, and I_0 is equal to A.

This equation fits the data whether V is the voltage on the anode or the surface potential (see Fig. 3), but for theoretical consideration, V should be the surface potential.

In the Townsend avalanche, I_0 is the initial current; *i.e.*, the electron current leaving the cathode. In the magnesium oxide cathode, I_0 may be defined as the current carried by those electrons leaving the nickel sleeve that cause the avalanches. This is a very small part of the total current. As determined from the experimental data, I_0 is some orders of magnitude less than I.

For every electron emitted there must be an electron transferred from the nickel sleeve to the oxide layer. Otherwise there would not be an equilibrium of charges. These electrons may be explained in terms of hole conduction. For example, whenever there is an inelastic collision during the avalanche process that results in the freeing of additional electrons, a corresponding number of holes are created in the oxide. These holes are free to move at substantially slower speeds back toward the nickel base. They are equivalent to the positive ions in the Townsend discharge. Hole mobility in magnesium oxide has been measured by Yamaka and Sawamoto[7] and found to be approximately 2 cm^2 per volt second.

Not much is known about the band-gap structure of magnesium oxide as used in this cathode, but it seems safe to assume that it is fairly complicated and contains a good many energy levels within the gap. Thus an electron need not traverse the whole band-gap of pure magnesium oxide, which is greater than 7.3 volts,[8] in order to become available as a conduction electron. Traps, impurity levels, etc. may all be expected to play important roles.

The voids in the porous layer provide a longer path for accelerating the electrons than their mean free path in the solid magnesium oxide. Thus it may be in the voids that the electrons acquire enough energy to enable them to ionize and produce avalanche multiplication.

At the surface the electrons arrive with a wide distribution of velocities because of the different amounts of acceleration they have recieved from the field. Many of these electrons have velocities in excess of the 2.8 volts[8,9] required to pass through the surface. Outside the surface there is another weaker electrostatic field caused by the anode potential, which serves to remove a sufficient number of electrons from the vicinity of the surface, to maintain the positive surface charge needed for equilibrium.

The blue glow is believed to be due to processes associated with electron-hole recombination within the layer. It extends into the ultraviolet region and undoubtedly plays a role in releasing electrons from the nickel base.

Starting

Merely applying voltage (even high voltage) to the anode is not sufficient to start the emission. The following starting means have been successfully employed: ultraviolet light, intense visible light, radioactivity, electron bombardment, and the discharge from a Tesla coil. In each case there is a delay between the time of the application of starting means and the actual starting of the emission. The slowest starting means was radioactivity, requiring several minutes. With ultraviolet or visible light the starting time depends on the intensity of the radiation. Starting times of less than a second have been obtained with intense light. The discharge of a Tesla coil on the outside of the bulb will start the

[7] E. Yamaka and K. Sawamoto, "Photo induced Hall effect in MgO," *Phys. Rev.*, vol. 101, pp. 565–566; January, 1956.

[8] H. R. Day, "Irradiation-induced photoconductivity in magnesium oxide," *Phys. Rev.*, vol. 91, pp. 822–827; August, 1953.

[9] J. B. Johnson and K. G. McKay, "Secondary electron emission in crystalline MgO," *Phys. Rev.*, vol. 91, pp. 582–587; August, 1953.

emission in a second or less. Electron bombardment can be even faster depending on its intensity as described below.

In all of these starting means, it is believed that either photo-electrons or secondary electrons are released from the surface by the starting operation, and that this loss of electrons charges the outer surface of the magnesium oxide layer positively to its operating potential.

One of the first "built in" starters tried employed field emission from a sharp tungsten point. Fig. 7 shows its position in a diode. The plate shield, which was grounded, was used in tubes with a collector grid to prevent wall charging. The tungsten point was one micron in diameter, and at a negative potential of 1000 volts the emission started in from 0.1 to 2 seconds with point emission of less than 0.01 microampere. This delay in starting was due primarily to the time required for the spread of the emission over the whole area of the cathode. The requirement of a high negative potential for the point was undesirable and this starting means was abandoned.

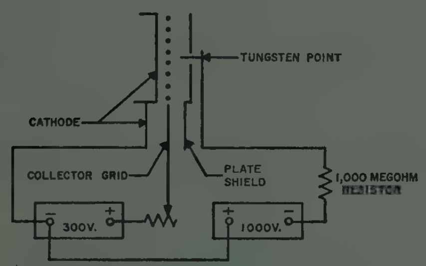


Fig. 7—Arrangement of tungsten point in diode for field emission starting.

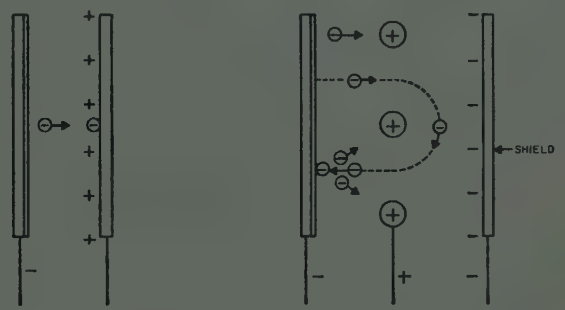
The starter now employed in all tubes consists of a short length of 1 per cent thoriated tungsten filament that is brought up to electron-emitting temperature momentarily. It starts the emission in less than a second, the time required being partly that needed to bring the filament up to operating temperature. The filament dimensions are 0.50 inch long by 0.0022 inch in diameter. It is located behind the grid support wires (see Fig. 10) so that contaminants, which may be evaporated from it and which travel in straight lines in the vacuum, cannot reach the cathode surface. It is normally connected to the nickel cathode sleeve internally, and no extra voltage is needed except that required to bring it to 1600°C, which is its operating temperature. This is normally 1.9 volts and 0.58 amperes and may be ac or dc.

It is believed to operate as follows. Some of the light that it emits is reflected onto the cathode, causing the release of photo-electrons which start charging the cathode surface positively. When the surface potential reaches a value where the secondary to primary ratio is greater than unity, electrons from the filament, either directly over curved paths or reflected from the positive tube elements, bombard the cathode to start the emission.

In simple diodes it has been found that if a grid is used as the anode the cathode will start more easily than if the anode is a solid plate.[10]

Fig. 8(a) shows a schematic representation of a MgO cold cathode with a plate rather close to the cathode. Fig. 8(b) represents a cold cathode with the plate replaced by a positive grid, beyond which lies a grounded shield. In Fig. 8(a) two factors tend to inhibit starting. 1) The plate acts as a shield against excitation of the cathode surface by whatever means may be used for starting. 2) Electrons are attracted to the plate without return.

In Fig. 8(b), on the other hand, excitation of the cathode is facilitated by spaces in the emission-sustaining grid. While some electrons reach the grid laterals, others miss them, and travel through the space in a parabolic path, returning to the cathode where they strike it with an energy that is equivalent to their initial velocity. Since magnesium oxide is a good secondary emitter, these returning electrons will generate secondaries with a ratio greater than unity at velocities well within the range of the returning electrons. Secondaries so produced aid in pulling the surface potential up to operating values. This is illustrated in the figure.



(a) (b)

Fig. 8—Electron paths in diode with plate anode, A, and grid anode, B.

The ease in starting emission with a wire or mesh grid is reduced when the shield, or plate, beyond the grid is positively biased to the same or to a higher potential. In this case electrons do not return to the cathode. In accord with these observations, amplifier tubes provided with starter filaments are presently so connected in their operating circuits that the plate circuit is opened up momentarily while operating the starter.

Keep-Alive Operation

It has been found that the emission is sustained at very low current densities. This provides a "keep-alive" feature. Furthermore, with the cathode sustaining emission at a low current, full emission may be restored in a very short time. For example, if the keep-alive current is a few microamperes/cm² the time required for full emis-

[10] This should not be interpreted to mean that a grid is necessary. Diodes without grids and with simple plates for the anodes do start and operate satisfactorily.

sion restarting is approximately one millisecond. At higher keep-alive currents the restarting time is even less.

This high restarting speed suggests that the keep-alive current is not confined to any one spot of emission on the cathode, but must be at least fairly well distributed over its surface. Otherwise the time required for emission to spread over the cathode surface from one point, as in field emission point starting, would be much greater than that measured. The blue glow at keep-alive currents is too faint to be seen. Life tests of tubes at keep-alive current densities have shown no deterioration even after 2 years of continuous operation.

Noise

Noise studies have been made on diodes similar to those used for obtaining the emission characteristics, but with a shield around the structure to prevent glass wall charging. It was found that the noise usually increased with decreasing frequency, that it had a crackling, rushing sound, and that for a frequency band from 3 to 200,000 cycles its magnitude was much greater than shot noise for the same current. Furthermore, microscopic examination of the emitting surface showed minute variations of intensity with time at various small areas on the cathode surface, similar in general to the localized variations in emission of the thermionic cathode. All of these facts indicated that the major component of noise was due to flicker effect.

For thermionic cathodes, the flicker-effect-noise level varies a great deal not only from type to type but from tube to tube of the same type.[11] It has been found that this is also true of the MgO cold cathode.

Life

In the operation of the barium-strontium-oxide cathode under ideal conditions there is a continual evaporation of barium oxide from the surface which gradually reduces the emissivity. When the depletion of these chemicals is nearly complete the end of life point is reached.

In contrast to this, no depletion of any kind has been detected during the operation of this magnesium-oxide cathode. The surface remains stable and chemically inert. Thus a long operating life may be expected. One of the early diodes was put on life test at a current drain of 4 ma (2.9 ma/cm^2). No increase or decrease of emission occurred for 14,000 hours. Most cathodes have had shorter lives but this one example sets the objective of further development.

Grid Control in Amplifying Tubes

A requirement for sustained emission is that the outer surface potential of the cathode coating be maintained at a high positive value. This in turn requires that there be a positive potential gradient between this surface and the first element. The potential in the plane of the grid nearest the cathode, therefore, must be nearly 200 volts positive with respect to the nickel cathode sleeve. This requirement must be met whether this first grid is the emission sustaining element or the control grid.

If the first grid is the sustaining grid, it is followed by the control grid which operates at a lower potential, but is still positive with respect to the cathode nickel base. For this grid arrangement, a virtual cathode is apparently produced in front of the control grid. Successful amplifying tubes have been made experimentally in this design.

If the first grid is the control grid as in a conventional tube, then the second grid is the sustaining element, operating at a substantially higher potential than the first grid, so that the average potential in the plane of the first gird is always positive enough to sustain the emission. The pentode described below combines these two types of grid control

Characteristics of Pentode

Fig. 9 shows the internal structure of the pentode. The plate is cut away in front so that the parts are visible. All parts are standard receiving-tube parts except for the cathode coating. There is a heater of the usual kind inside the cathode sleeve that is used during processing. It is never energized after the tube is sealed off of the pumps.

Fig. 9—Photograph of internal structure of pentode amplifier tube. Glass bulb has been removed and plate has been cut away.

[11] A. Van der Ziel, "Noise," Prentice-Hall, Inc., New York, N. Y., p. 225; 1954.

Fig. 10 shows a horizontal section through the tube. The second grid, G_2, is the emission sustaining grid. The first grid, G_1, and third grid, G_3 are tied together to give a double control as discussed above. Thus the tube has neither screen nor suppressor grid, and its action is more nearly like a triode than a conventional pentode.

The starter filament is outside the main structure, but in line with a window in the plate. Light and electrons that it gives off can find their way to the cathode, unlike contamination which travels in straight lines in a vacuum.

Fig. 11 is a vertical section through the tube structure drawn to scale showing the dimensions of the parts.

Fig. 12 is the grid characteristic, showing a transconductance of 600 micromhos. This has been confirmed by dynamic measurements.

Fig. 13 gives the plate family of curves. These were

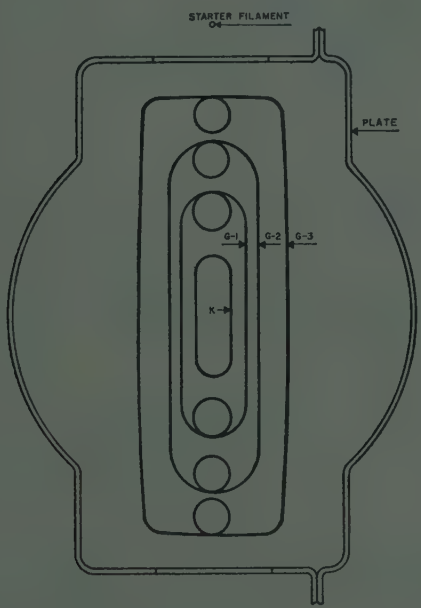


Fig. 10—Section through pentode taken perpendicular to axis and drawn to scale.

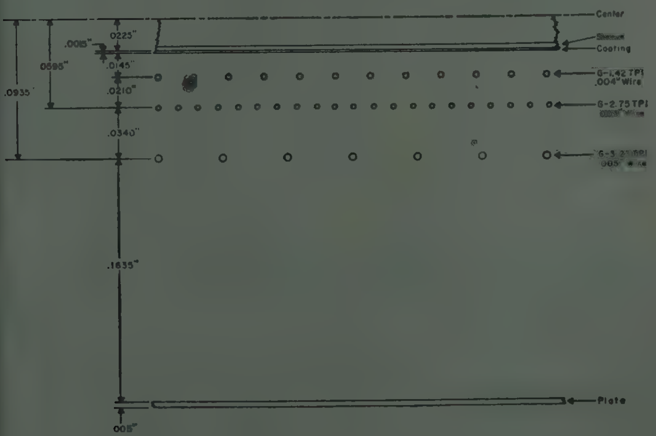


Fig. 11—Section through pentode taken parallel to axis and drawn to scale.

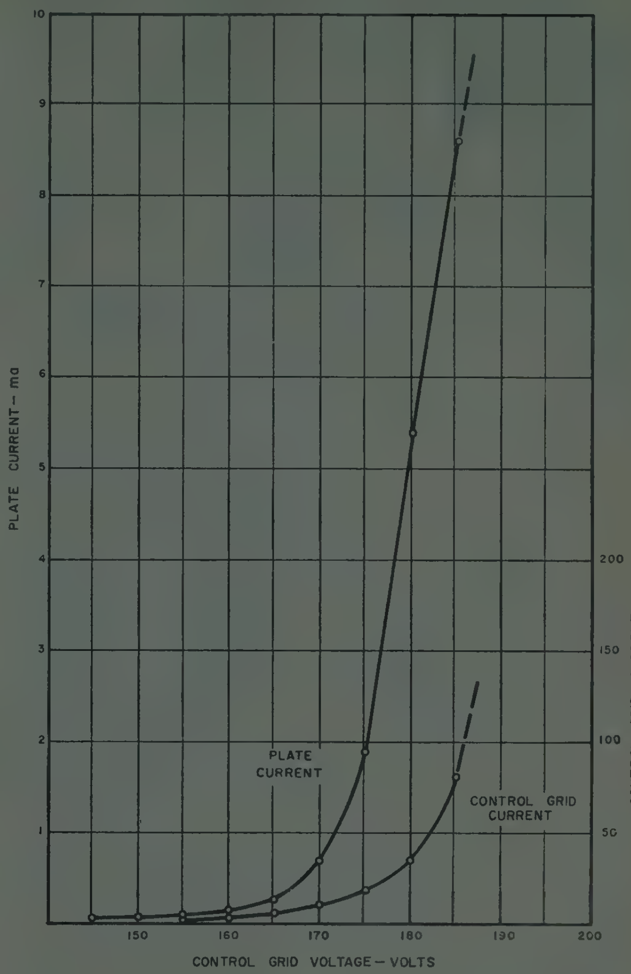


Fig. 12—Control grid characteristic of pentode. The control grid actually consists of G_1 and G_3 connected together. Plate voltage =450, sustaining grid supply voltage=450, sustaining grid resistor=10,000 ohms.

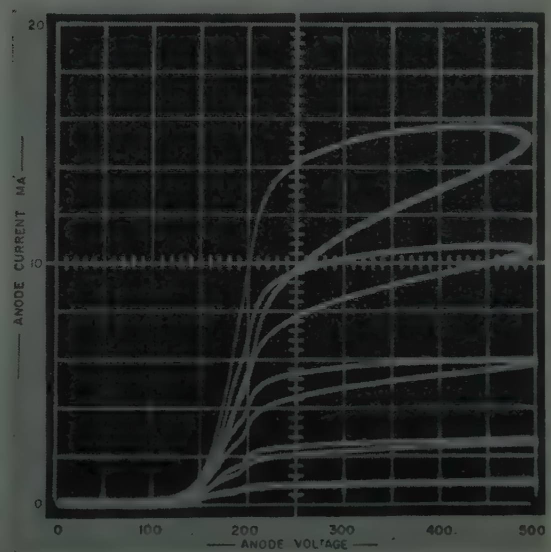


Fig. 13—Family of curves of plate current vs plate voltage for the pentode. The different curves were taken at 160, 170, 180, 190, and 200 volts on the control grids. The sustaining grid was operating at an average value of 420 volts.

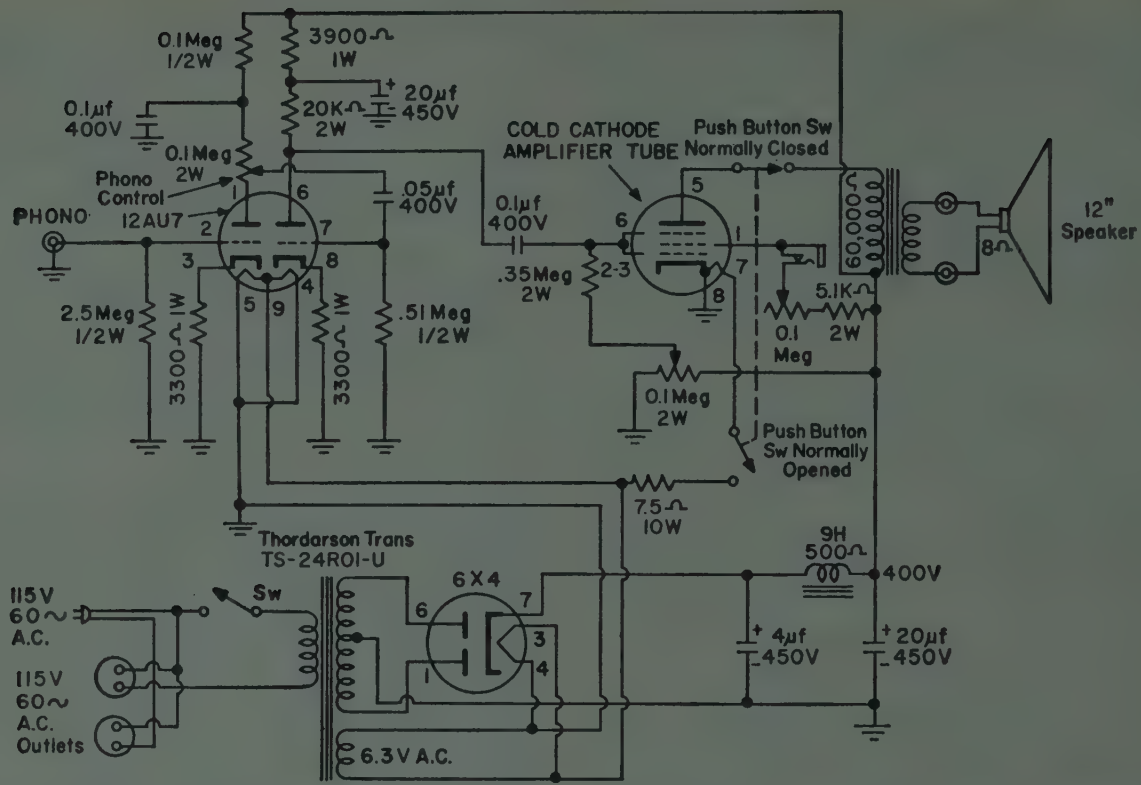


Fig. 14—Circuit of audio amplifier employing the cold cathode pentode in the output stage, which was used for demonstration.

taken on an automatic curve tracer with a repetition rate of 60 cycles. The loops that appear at the higher values of plate current appear to be due to a lag in surface charge, *i.e.*, surface potential, as the applied potential is varied.

The following are the operating characteristics.

Plate supply voltage	500 volts
Plate current	10 ma
Sustaining grid (G_2) voltage supply	350 volts
Sustaining grid (G_2) resistor	10,000 ohms
Sustaining grid (G_2) current	3 ma
Control grid (G_1+G_3) voltage	175 volts
Transconductance	600 micromhos
Amplification factor	$33\frac{1}{3}$
Plate resistance	55,500 ohms

Fig. 14 shows the circuit that was used with the pentode in the output stage of a small phonograph for demonstration purposes.[12] The output was 900 milliwatts of audio power with less than 5 per cent distortion. The signal to noise ratio in the output circuit was 52 db.

Acknowledgment

The authors wish to acknowledge the many helpful discussions with L. L. Kaplan and Dr. D. Dobischek of the Signal Corps, during the preparation of this paper.

A number of members of the technical staff of the Tung-Sol Research Division have contributed significantly. In particular the names of W. J. Shattes, R. L. Simpson, and W. C. Johnson should be mentioned.

[12] Demonstrated at the Meeting of Electron Devices Section of the IRE, Washington, D. C., October 31, 1958.

The Quadrupole Amplifier, a Low-Noise Parametric Device*

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Summary—**Unusually low noise, combined with high stable gain over fairly wide bands, has been obtained with electron beam amplifiers of a new kind. This paper explains how this performance is achieved by the action of a transverse quadrupole field upon a fast cyclotron wave.**

The first two sections give a qualitative description of the device and of the amplifying mechanism. A physical picture of the fast cyclotron wave is used to explain the interchange of signal and noise in the input coupler and the mechanism of parametric amplification in the quadrupole region.

The third section presents a detailed analysis of the amplification process. It shows that the fast cyclotron wave is amplified in accordance with a cosh function of distance traveled through the quadrupole, and that a new cyclotron wave at idler frequency (difference between pump and signal frequencies) is generated which grows as a sinh function of distance.

The fourth section describes experimental tubes built to date. These operate on frequency bands between 400 and 800 mc. Typical bandwidth is 40 to 50 mc independent of gain, which may be adjusted to 20 or 30 db. Residual noise temperature of the electron beam in good specimens within this experimental lot is 70°K; input coupler loss raises this figure to about 100°K. This is equivalent to a noise figure of 1.4 db if the device is used, for instance, in radio astronomy. As with other parametric devices, a correction must be added in many other applications; its amount depends on the specific arrangement. This is explained in some detail in the fourth section.

The last section attempts to state precisely the concepts on which the quadrupole amplifier is based and which distinguish it from conventional devices. These concepts may generate a variety of new tube structures in addition to the one described.

Introduction

THE quadrupole amplifier is a tube in which quadrupole fields act parametrically upon the fast cyclotron wave of an electron beam to produce the amplification.[1] In more conventional microwave tubes such as the traveling-wave tube and the klystron, it is through interaction with a slow wave of the beam that amplification results.[2,3] The slow wave used can be either a space-charge wave or a cyclotron wave (although the use of space-charge waves is more common in this respect). It has been established theoretically that after the beam emerges from the gun the noise present in slow waves of either type cannot be completely removed or cancelled.[4,5] On the other hand, complete noise removal or cancellation is possible, in principle, for a fast wave of either type. Consequently workers have recognized for some time that amplification by means of a fast wave could well be an attractive method of obtaining low-noise amplification.[6–9] In the quadrupole tube, amplification by this means is accomplished.

Several of these tubes, all designed to operate in the 400 to 800 mc region, have been built and tested. They exhibit a number of unusual properties. Noise temperature in the liquid nitrogen range has been measured. The tubes are completely unilateral and unconditionally stable. The present tubes have bandwidths of about 10 per cent. Inherently such tubes are capable of much greater bandwidth since, as is shown in a later section, the amplifying process does not limit the bandwidth at all. The bandwidth for a given tube is determined substantially by the bandwidth of the input and output couplers. These and other experimental results are described in more detail in a section to follow.

The quadrupole amplifier is shown diagrammatically in Fig. 1. The electron gun produces a beam which flows successively through an input coupler, an amplifying region, and an output coupler. The entire beam is immersed in a uniform magnetic field (not shown in the diagram) and flows parallel to the flux lines. Most

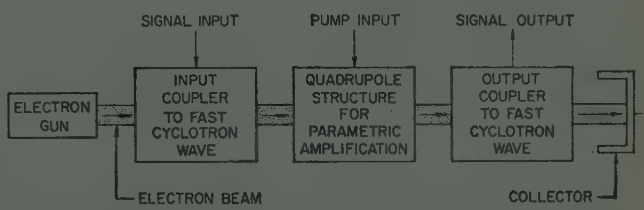

Fig. 1—Diagram of quadrupole amplifier.

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[1] R. Adler, G. Hrbek and G. Wade, "A low-noise electron-beam parametric amplifier," Proc. IRE, vol. 46, pp. 1756–1757; October, 1958.

[2] J. R. Pierce, "The wave picture of microwave tubes," *Bell Sys. Tech. J.*, vol. 33, pp. 1343–1372; November, 1954.

[3] R. W. Gould, "A coupled mode description of the backward-wave oscillator and the Kompfner dip condition," IRE Trans. on Electron Devices, vol. ED-2, pp. 37–42; October, 1955.

[4] H. A. Haus and F. N. H. Robinson, "The minimum noise figure of microwave beam amplifiers," Proc. IRE, vol. 43, pp. 981–991; August, 1955.

[5] H. A. Haus and D. L. Bobroff, "Small signal power theorem for electron beams," *J. Appl. Phys.*, vol. 28, pp. 694–704; June, 1957.

[6] R. Adler, "A new principle of signal amplification," presented at Conf. on Electron Tube Research, Berkeley, Calif.; June, 1957.

[7] W. H. Louisell and C. F. Quate, "Parametric amplification of space-charge waves," Proc. IRE, vol. 46, pp. 707–716; April, 1958.

[8] R. Adler, "Parametric amplification of the fast electron wave," Proc. IRE, vol. 46, pp. 1300–1301; June, 1958.

[9] G. Wade and R. Adler, "A new method for pumping a fast space-charge wave," Proc. IRE, vol. 47, pp. 79–80; January, 1959.

of the tubes thus far built operate with the magnetic field intensity such that the corresponding cyclotron frequency is approximately equal to the frequency of the signal to be amplified. For these tubes, the input and output couplers are of the Cuccia type.[8,10] This type of coupler interacts with the fast cyclotron wave only. The input coupler serves two functions. It demodulates the beam as far as the entering fast-wave component of beam noise is concerned, and at the same time it modulates the beam with a new fast wave corresponding to the input signal. Thus it extracts noise and inserts signal simultaneously. The beam then passes through the quadrupole structure which provides a means for amplifying the signal modulation. In the present tubes the quadrupole is fed by a pumping signal at precisely twice the cyclotron frequency. Parametric action of the quadrupole field upon the modulated beam results in amplification. Finally, the amplified fast-wave modulation is extracted from the beam by the output coupler and appears as the signal output for the device.

Since the action of the quadrupole field is parametric in nature, these amplifiers exhibit a number of the characteristics usually associated with parametric amplifiers. For example, a modulation at the idler frequency (the difference between the pump frequency and the input signal frequency) is excited on the beam by the quadrupole fields and will appear at the output if the output coupler is sensitive to the idler frequency.

Although certain similarities do exist between the various types of parametric amplifiers, there are also some wide differences. For example, the quadrupole amplifier is not inherently narrow band, bilateral nor unstable, as is common in many cavity type, solid-state versions. The quadrupole has opposite characteristics in these respects. In many ways it resembles the tube of Louisell, Quate and Ashkin[7,11] which utilizes parametric amplification of space-charge waves. However, there are some significant differences having to do with the nature of the qudarupole pumping and with the inherent behavior of cyclotron waves relative to space-charge waves.[12]

In the sections to follow, this paper presents a more detailed physical description of the amplifier and how it works, an analysis of the amplifying mechanism associated with the quadrupole fields, a discussion of the experimental results, and some conclusions regarding the significance of this work. Although the noise behavior is discussed in a general way and the results of noise figure measurements are given, an analysis of the noise characteristics of cyclotron waves is not presented, since this appears in the literature elsewhere.[5,13]

Physical Description of the Device and the Mechanisms for Coupling and Amplifying

Since this device amplifies the fast cyclotron wave, it is necessary to know something about the nature of the fast cyclotron wave in order to understand how the device works. Analyses of the various cyclotron waves are available in the literature.[13–16] It will suffice here to summarize briefly what the analyses say with particular emphasis on the fast wave.

Consider an electron beam drifting in a region of uniform magnetic field. The unmodulated beam flow is parallel to the flux lines of the field. If the beam is modulated by a signal that produces velocity components in the transverse direction, in general, the modulation components are propagated along the beam corresponding to two fundamental modes, a fast-wave mode and a slow-wave mode.[17] The phase velocities of propagation for these modes are, respectively,

$$v_f = \frac{u_0}{1 - \dfrac{\omega_c}{\omega}}$$

and

$$v_s = \frac{u_0}{1 + \dfrac{\omega_c}{\omega}},$$

where

u_0 = the electron velocity in the axial direction (the direction of unmodulated beam flow),
$\omega_c = \eta B$, the radian cyclotron frequency,
ω = the radian frequency of the signal modulation,
η = the electronic charge to mass ratio,
B = the strength of the axial magnetic field.

As the signal frequency approaches the cyclotron frequency from above, the separation of the velocities increases. For the case where the signal frequency equals the cyclotron frequency, the phase velocity for the fast

[10] C. L. Cuccia, "The electron coupler," *RCA Rev.*, vol. 10, pp. 270–303; June, 1949.

[11] A. Ashkin, "Parametric amplification of space charge waves," *J. Appl. Phys.*, vol. 29, pp. 1646–1651; December, 1958.

[12] For example, the pumping fields producing the amplification are supplied by the quadrupole structure rather than through a separate modulation of the beam. This eliminates the problem of beam saturation and the detrimental by-products associated with beam saturation. Also, with cyclotron waves the fast and slow waves can be more easily separated in velocity than with space-charge waves.

[13] G. Wade, K. Amo, and D. A. Watkins, "Noise in transverse-field traveling-wave tubes," *J. Appl. Phys.*, vol. 25, pp. 1514–1520; December, 1954.

[14] J. R. Pierce, "Traveling-Wave Tubes," D. Van Nostrand Co., Inc., New York, N. Y., ch. 13; 1950.

[15] R. Adler, "An equivalence principle in high frequency tubes," 1953 IRE National Convention Record, pt. 6, pp. 54–61.

[16] R. Adler, O. M. Kromhout, and P. A. Clavier, "Transverse-field traveling-wave tubes with periodic electrostatic focusing," Proc. IRE, vol. 44, pp. 82–89; January, 1956. See particularly "Transverse electron waves," pp. 84–85.

[17] Transverse waves can also propagate at an intermediate velocity equal to the electron stream velocity u_0. These waves involve transverse displacements only, with zero transverse velocity components (see reference 13). These waves are not germane to the present discussion since they are not generated by the input coupler and are not amplified by the quadrupole structure.

wave is infinite. The phase velocity for the slow wave is one-half the axial electron velocity. The two velocities are then very different, and it is easy to couple to the fast wave only. The quadrupole amplifiers thus far built have operated over a range of signal frequencies close to the cyclotron frequency.

For a moment, consider the electron pattern corresponding to fast wave modulation only. Fig. 2 illustrates the pattern as it would appear at a particular instant of time for the condition that $\omega > \omega_c$. The imaginary center conductor is included as a convenience for indicating the sense of the helical pattern. As time passes, the pattern maintains its form but moves forward in the plus z direction at the fast-wave velocity. Each electron individually moves forward at u_0, which is less than the fast-wave velocity. It is possible for the pattern to move faster than the electrons because each electron has angular velocity in the plus θ direction (*i.e.*, coming out of the paper above the center conductor and going into the paper below the center conductor) as well as linear velocity in the plus z direction. The angular velocity of each electron in the plus θ direction is precisely ω_c, the radian cyclotron frequency. The point of intersection of the beam with any transverse plane at constant z describes a circle and moves with an angular velocity of precisely ω, the radian frequency of the modulation.

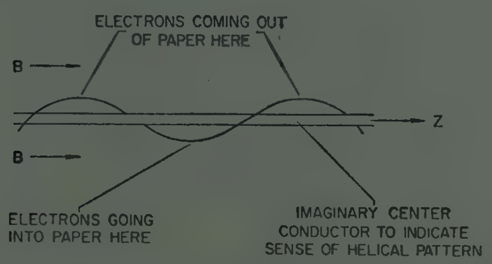

Fig. 2—Electron pattern corresponding to fast-wave modulation on a drifting beam for an instant of time. The beam is assumed to be immersed in a uniform magnetic field B. Also it is assumed that $\omega > \omega_c$.

As stated, Fig. 2 gives the pattern under the condition $\omega > \omega_c$. As ω is reduced, both the fast-wave velocity and the wavelength increase. The helical beam pattern becomes less tightly wound. It is important to note that in spite of these changes in the beam pattern, the individual electrons continue to move in the axial direction with velocity u_0 and in the θ direction with angular velocity ω_c. In the limit, as ω approaches ω_c, the beam pattern becomes a straight horizontal line which revolves about the axis (or the imaginary center conductor of Fig. 2) with angular velocity $\omega = \omega_c$. The phase velocity and the wavelength are both infinite for this condition.

For $\omega < \omega_c$, the phase velocity becomes negative. This merely means that the beam pattern shown in Fig. 2 begins to wind up the other way, becoming a right-handed instead of a left-handed screw. The individual electrons still revolve with angular velocity ω_c while moving forward with velocity u_0.

For operation where the cyclotron and the modulation frequencies are about equal, the phase velocities are so high that we can neglect the time of propagation and use lumped electrodes, as in the present quadrupole tubes. For example, each coupler consists of a pair of flat, parallel plates between which the beam flows. Let us examine briefly the nature of the couplers by following a beam as it passes from an electron gun successively through an input coupler of this type, a drift region, and an output coupler of this type. Fig. 3 illustrates the operation when the cyclotron and modulation frequencies are precisely equal. In the input coupler, each electron follows a spiral path of increasing radius. Then it continues on a helical path of constant radius in the drift region preceding the output coupler. Cuccia has shown that if the output coupler is loaded properly, the circling electrons can be made to give up all their transverse motion as they pass through it.[10] There is no energy interchange between transverse and longitudinal electron motion. There is also no gain. To the signal source, the electron stream in the input section looks like a purely resitive load. All the energy delivered by the source is turned into transverse electron motion and it all reappears in the output coupler.

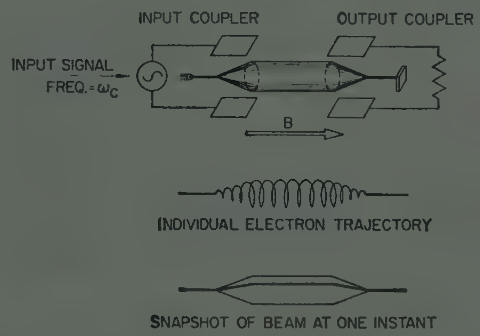

Fig. 3—Diagram showing an electron beam passing through an input coupler and an output coupler which are separated by a drift region. The individual electrons follow spiral and helical paths, while the beam pattern for any instant of time consists of straight line segments.

The mechanism of energy interchange between beam and coupler is similar to energy interchange in two coupled transmission lines. For properly designed coupling between two transmission lines, all of the energy originally fed into one of the two lines is transferred to the second one over a distance of a quarter of a coupling wavelength. If at this point we separate the two lines, the first line remains with none of its original energy and the second line carries away all of it. The same process, of course, works just as well in the opposite direction. In fact, if we have two sources of energy initially feeding the two lines (one source feeding each line) at the end of the coupling region the energy is completely interchanged. Assume that we label the energy fed to the first line "signal" and the energy fed

to the second line "noise." Then "signal" and "noise" are interchanged on the lines by the coupling.

The electron beam and the Cuccia coupler can be thought of as two coupled transmission lines each supporting waves of infinite phase velocity. A signal fed to the coupler is transferred to the fast wave of the beam while fast-wave noise entering with the beam is transferred to the coupler. Ideally the device shown in Fig. 3 transmits all of the signal and adds no noise to it.

We may regard each coupler as a three-port circulator. The first port consists of the beam as it enters; the second port, the leads to the two parallel plates; and the third port, the beam as it leaves. The fast-wave noise which enters the first port (i.e., with the beam) goes out the second port to the signal source which also acts as a noise sink. The signal energy from the source enters the second port and is routed to the third port (the departing beam). If the noise sink is not properly matched, a fraction of the beam noise is reflected and reapplied to the beam.

The Cuccia coupler, because of its requirement of infinite phase velocity, represents a special case among fast-wave couplers. Such couplers may also be designed for finite phase velocity; helices are a familiar example. Signal input and beam noise output terminals may be physically separated on such a coupler, making it effectively a four-port circulator.

As shown in Fig. 3, when $\omega=\omega_c$, the beam pattern in the drift region forms a straight, horizontal line segment which revolves about the axis with an angular frequency ω_c. Each electron in the drift region follows a helical path of constant radius. The fact that the radius is constant signifies that no amplification takes place. Any mechanism which increases the radius of the electron path will produce amplification. For the amplification to be linear, the rate of growth of the radius must be proportional to the radius.

The problem of producing amplification is one of finding a mechanism for increasing the radii of the individual electrons. Consider a single electron which in the absence of such a mechanism describes a circular path as far as its transverse motion is concerned. It seems intuitively obvious that the radius of the circular path could be increased by arranging for the electron to experience constantly a tangential force in the direction of its transverse motion. Such a force would serve to accelerate the electron, increasing its tranverse velocity and consequently increasing the radius of curvature of its path. In this regard, the electron motion would be somewhat similar to the motion of the bob of a circular pendulum (one which traces a circular orbit in a horizontal plane) when the bob is acted upon continuously by a tangential force which increases its velocity.

For the operation to be proper, the magnitude of such a tangential force on the electron would have to be a function of the position of the electron. An unmodulated electron, corresponding to no signal present, would travel without any transverse motion down the axis of the tube, in the absence of our hypothetical force system. This electron should be left undisturbed by our hypothetical force system. In order for the amplification of electron radii to be linear, an electron which carries a weak signal and consequently describes a path of small radius, should encounter only a weak tangential force. By the same token, an electron which is strongly modulated should encounter a strong tangential force. As the radius of curvature of the electron path increases, the magnitude of the force encountered should likewise increase.

Fig. 4 shows an electrode structure which is ideally suited to supply the forces necessary to amplify the radii of all electrons which enter with the proper phase. The figure represents the cross section at the entrance to a quadrupole structure. The structure is assumed to extend out of the paper in the positive z direction. The polarities indicated in the figure correspond to an instant when the top and bottom electrodes are at their maximum positive potential and, consequently, when the left and right electrodes are at their maximum negative potential. The arrows show the forces which would be exerted upon electrons in the corresponding positions.

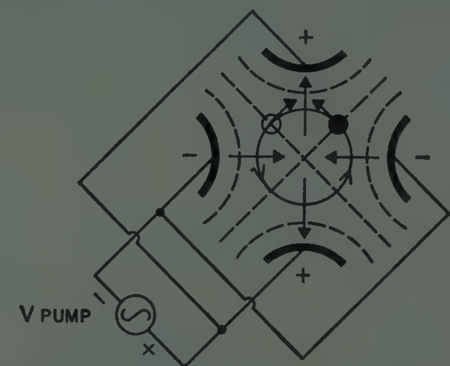

Fig. 4—Cross section at the entrance to the quadrupole structure, illustrating the forces exerted upon electrons (arrows) and the equipotential surfaces (dashed lines).

The beam flow is out of the paper and the sense of the helical electron motion is counter-clockwise as seen by an observer looking up stream at the cross section. The dashed lines indicate the equipotential surfaces of the quadrupole region. We see that the electron at the top right, which is shown solid, encounters a force which accelerates it along its counter-clockwise path. The other electron, shown at the top left as an empty circle, is subjected to a force which decelerates its orbital motion. Any electron which occupies a position along the equipotential line extending from upper right to lower left has the proper phase for maximum acceleration and therefore maximum amplification. Those occupying positions along the equipotential line extending from upper left to lower right will experience maximum deceleration.

Two entirely different approaches may be used to analyze the amplification process. The mathematical

treatment given in the following section resolves the orbital electron motion into two orthogonal periodic motions; it shows how each of these is made to grow by the application of a time-varying restoring force. This is the parametric viewpoint. It is helpful because it elucidates the analogies between the quadrupole amplifier and other parametric devices; it is also general enough to be applicable to other electron beam devices which use periodic electron motion about one coordinate only.[9]

But in the present device, the magnetic field forces the two orthogonal periodic motions to be always in phase quadrature and of equal amplitude. This restriction permits us to use a simpler method of analysis, less general but better suited to convey an intuitive understanding of the specific device.

We may resolve the alternating quadrupole field pattern into two counter-rotating component patterns, in the manner commonly used with electrical machines. Because our stator has four poles, the component patterns complete one revolution for every two cycles of the pump frequency. If we choose the pump frequency to be just twice the cyclotron frequency, one of the patterns will revolve synchronously with the orbiting electrons. The other pattern we may ignore, as far as our present description is concerned, because its influence is small.

For the moment, let us consider an electron which enters the quadrupole region with a phase corresponding to maximum acceleration. Half of the accelerating field may be ascribed to the quadrupole field pattern just referred to which rotates synchronously. Our electron, which entered with optimum phase, remains in that phase throughout its passage through the quadrupole. Note that there is no field at all at the center and that the field intensity increases linearly with distance from the center. Thus, the forces exerted upon our orbiting electron are proportional to the radius of the circle in which it moves. As a result, the radius increases exponentially and the amplification is linear.

Now let us consider an electron which enters with a phase corresponding to maximum deceleration. For this electron, the force field produces an exponential decrease in the radius which is equivalent to a linear attenuation. The rate of decrease in the radius for this electron and the rate of increase in the radius for the previous electron are the same. Fig. 5 shows the curved surfaces generated by the motion of two electrons with best and worst phase. Both are assumed to enter from the left along the same cylindrical surface. One radius becomes very large and the other negligibly small.

Thus far we have been discussing the motion of individual electrons. Fig. 5 can also be used to illustrate beam patterns. For example, assume that the pump frequency is precisely twice the cyclotron frequency and that the input frequency is accurately synchronized with one-half the pump frequency. A specific phase condition, for instance that of maximum gain, will then be maintained. Under these conditions the outer surface of Fig. 5 is a figure of revolution of the beam pattern. If the phase condition is changed to that of maximum attenuation, then the inner surface of Fig. 5 becomes the figure of revolution of the beam pattern. If the signal frequency is then altered slightly, conditions of maximum gain and maximum loss occur alternately. At any plane in the quadrupole the radius of the electron pattern as a function of time is periodic, swinging alternately from that corresponding to maximum gain to that corresponding to maximum attenuation. If the difference between one-half the pump frequency and the signal frequency is great enough, the electron pattern at any instant of time will touch several times both the maximum gain surface and the maximum attenuation surface. This condition is illustrated by the plot in Fig. 6. On the average, the resulting output signal is larger than the input signal because the exponential growth always outweighs the exponential drop. The output signal contains a beat with round tops and sharply pointed dips. It consists of two sine wave components, one at the signal frequency, and the other at the idler frequency, the difference between pump and signal frequencies.

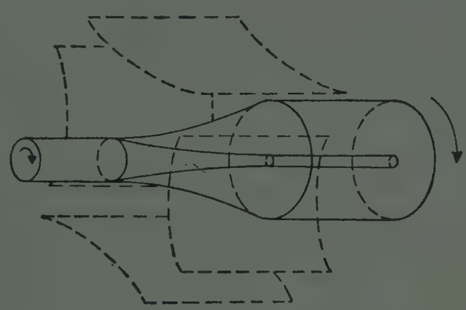

Fig. 5—Surfaces generated by the motion of electrons with best and worst phase for amplification. The dashed lines depict the outlines of the quadrupole structure.

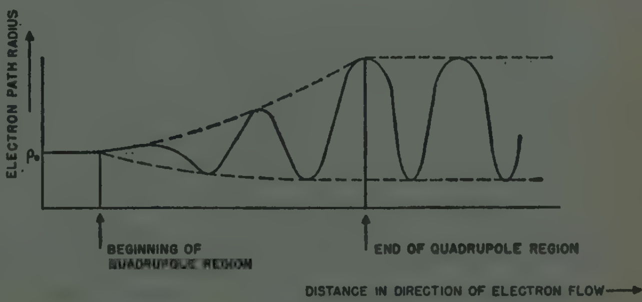

Fig. 6—Electron path radius as a function of distance for a particular instant of time.

It is now possible to see why the amplifying process does not limit the bandwidth. The waveform shown in Fig. 6 was obtained by altering the signal frequency. The pump frequency and the magnetic field were not changed. Gain resulted from averaging over many electrons entering with every possible phase. This mechanism remains the same regardless of signal frequency.

Thus the amplifying process does not have any frequency selectivity. By using wide-band couplers, we may produce fast waves at any signal frequency. The individual electrons which make up these waves must still orbit at the cyclotron frequency, and we can amplify their motion by pumping at twice that frequency. The bandwidth of the tube, therefore, is determined only by the couplers.

In comparing the action of the quadrupole with older amplifying mechanisms, one is struck by the absence of a familiar concept. There is no two-way interaction between a stream and a field, as in a traveling wave tube, or between two streams, as in a double-stream amplifier; instead, there is only the one-way action of an externally imposed field upon individual electrons.

Analysis of Amplifying Mechanism

This section presents a derivation of an equation describing the beam pattern in the quadruople region. By comparing the amplitude and the character of the transverse excursions at the end of the quadrupole region to the amplitude and character at the beginning, we obtain a measure of the gain of the amplifying signal and of the growth of the idling signal which is excited. The derivation proceeds by examining the nature of the quadrupole field and its effect upon the electrons of the beam.

Consider a quadrupole structure which is formed by placing four similar electrodes symmetrically about an axis. The electrodes are shaped so that the transverse cross sections of the structure are identical through all points of the axis. The structure is driven by tieing together the electrodes having opposite positions, and connecting the pump generator between the resulting pairs as illustrated in Fig. 4. The electrodes conceivably can have any of a wide variety of shapes. However, regardless of the shape, the equipotentials near the axis tend to have the form of equilateral hyperbolas. Equipotentials with precisely this form, not only near the axis but throughout the entire region, result if the electrodes themselves are shaped like equilateral hyperbolas. Since this shape gives the simplest field configuration for analysis and since all other shapes give field configurations which approximate this one near the axis (in the small signal region), we will assume that the electrodes are so shaped.

The potential anywhere in the quadrupole region is given by the following expression:

$$V = k(y^2 - x^2), \tag{1}$$

where x and y are the transverse coordinates specifying the position of the electrons. Fig. 7 illustrates the orientation of the coordinate system and the position of the electrodes. Electrodes 1 and 3 of Fig. 7 are connected together, as are electrodes 2 and 4. These connections were previously indicated in Fig. 4. The full pump voltage appears across the two pairs of electrodes.

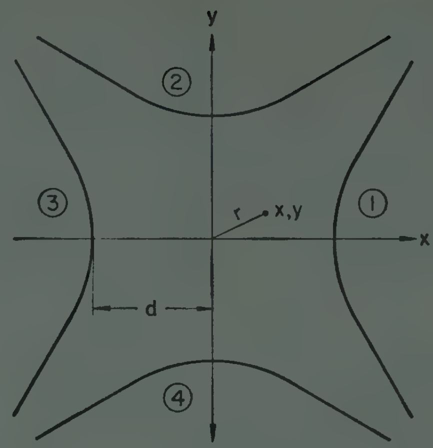

Fig. 7—Orientation of xy coordinates in the quadrupole region. Electron flow and magnetic flux lines are assumed to be in the z direction (out of the paper).

The quantity k is given by

$$k = \frac{V_{\text{pump}}}{2d^2}, \tag{2}$$

where V_{pump} is the instantaneous pump voltage and d is a distance defined in Fig. 7. As previously stated, the pump frequency is chosen to be just double the cyclotron frequency. Hence we have

$$k = \frac{V_m \sin 2\omega_c t}{2d^2} = k_m \sin 2\omega_c t \tag{3}$$

where k_m is a constant representing the maximum value of k. The x and y components of the electric field resulting from the pump voltage can be calculated from (1) as follows:

$$E_x = -\frac{\partial V}{\partial x} = 2kx$$

$$E_y = -\frac{\partial V}{\partial y} = -2ky. \tag{4}$$

Note that these field components are proportional to distance from the origin. The forces they produce upon electrons are therefore like elastic restoring forces. They vary in time at a rate corresponding to the pump frequency $2\omega_c$. This is characteristic of parametric processes.

We can determine the gain of the amplifier by observing the growth in the transverse displacement of the electrons as they traverse the quadrupole region. The procedure will be to consider the forces acting on a single electron. From this consideration we derive a general equation giving the transverse coordinates of the electron as a function of the time it remains in the quadrupole region. As we shall see, the relative phase of the pump voltage greatly influences the change in the transverse displacement of the electron. By applying the general equation thus derived to the whole train of electrons which make up the beam pattern, we obtain the

expression for beam position as a function of time at the plane marking the exit from the quadrupole region.

The force equation for a single electron is

$$\overline{F} = m\frac{d\bar{v}}{dt} = -e(\overline{E} + \bar{v} \times \overline{B}). \tag{5}$$

By expanding into x and y components of force, and using (4), we obtain

$$\begin{aligned} \ddot{x} &= -\eta 2kx - \omega_c\dot{y} \\ \ddot{y} &= \eta 2ky + \omega_c\dot{x}, \end{aligned} \tag{6}$$

where ω_c, the cyclotron frequency, is given by $(e/m)B$.

The electron beam which approaches the quadrupole region has already passed through the input coupler where it has been fast-wave modulated in the fashion previously described. The intersection of the beam pattern and the entrance plane to the quadrupole region moves in accordance with the following equations:

$$\begin{aligned} y &= r_0 \sin \omega t \\ x &= r_0 \cos \omega t, \end{aligned} \tag{7}$$

where ω = the modulating frequency (the input signal frequency). Eqs. (7) are consistent with the previous description of fast-wave modulation. The point of intersection of the beam and the entrance plane describes a circle and moves in the counter-clockwise direction at an angular velocity ω.

Let us consider a particular electron which enters at a time $t = t_1$. At that moment the electron has a transverse position given by

$$\begin{aligned} y &= r_0 \sin \omega t_1 \\ x &= r_0 \cos \omega t_1. \end{aligned} \tag{8}$$

In solving for the effect of the quadrupole fields on the transverse motion of the electron, it is helpful first to note the transverse motion of the electron under the condition that the quadrupole fields are zero. This transverse motion is readily obtained from (6) by letting k be zero and by using (8) to give the boundary conditions. For time $t > t_1$, the electron has been in the quadrupole region an amount of time $\tau = t - t_1$. The transverse motion of the electron is

$$\begin{aligned} y &= r_0 \sin (\omega_c\tau + \omega t_1) \\ x &= r_0 \cos (\omega_c\tau + \omega t_1). \end{aligned} \tag{9}$$

Eqs. (9) are consistent with intuitive concepts. After entering the quadrupole region with a transverse position given by (8), the electron describes a circle moving with angular velocity ω_c in the counter-clockwise direction.

For reasons which become apparent shortly let us expand (9), through the use of trigonometric identities, to give the following:

$$\begin{aligned} y &= r_0' \sin (\omega_c\tau + \omega_c t_1) + r_0'' \cos (\omega_c\tau + \omega_c t_1) \\ x &= r_0' \cos (\omega_c\tau + \omega_c t_1) - r_0'' \sin (\omega_c\tau + \omega_c t_1) \end{aligned} \tag{10}$$

where

$$\begin{aligned} r_0' &\equiv r_0 \cos (\omega t_1 - \omega_c t_1) \\ r_0'' &\equiv r_0 \sin (\omega t_1 - \omega_c t_1). \end{aligned}$$

Since $t = \tau + t_1$, (3) can be rewritten as follows:

$$k = k_m \sin [2(\omega_c\tau + \omega_c t_1)]. \tag{11}$$

We recognize that (10) is the solution for (6) in the limit as k_m approaches zero. For $k_m > 0$, the solutions must be modifications of (10), which approach (10) as k_m approaches zero. We are now in a postion to determine the modifications.

An easy method for finding the modifications (in fact, the method originally used by the authors) involves making use of the descriptive information previously given concerning the operation of the tube. We simply choose convenient entrance conditions to consider for the electrons and guess at the corresponding solutions. The accuracy of each guess is quickly determined by substituting the assumed solution in (6) and checking for equality. In this fashion we very rapidly arrive at the general solution which holds for all electrons regardless of entrance condition. As is shown below, only two choices of the entrance conditions are needed in finding the general solution.

For the first choice let us assume that t_1 is such that

$$\omega t_1 - \omega_c t = \pi 2n \qquad n = 0, 1, 2, \cdots.$$

Then

$$r_0' = r_0$$

and

$$r_0'' = 0.$$

If we compare (10) with (11) we see that for the above condition the electron has a phase which corresponds to that of the electron shown solid in Fig. 4, and therefore the electron experiences maximum amplification, as previously discussed. We might reasonably expect its radius to increase approximately as $e^{\alpha'\tau}$ where α' is some positive number. Hence, we guess that the solution is

$$\begin{aligned} y &= r_0 e^{\alpha'\tau} \sin (\omega_c\tau + \omega_c t_1) \\ x &= r_0 e^{\alpha'\tau} \cos (\omega_c\tau + \omega_c t_1). \end{aligned}$$

When we substitute this assumed solution in (6) we find that equalities result for

$$\alpha' = \frac{k_m}{B}$$

under the condition that

$$\alpha' \ll \omega_c.$$

This is the condition of usual interest.

For the second choice of entrance conditions let us assume that t_1 is such that

$$\omega t_1 - \omega_c t_1 = \pi(2n + 1) \qquad n = 0, 1, 2, \cdots.$$

Then

$$r_0' = 0$$

and

$$r_0'' = r_0.$$

This time the electron has a phase corresponding to that of the electron shown as the empty circle in Fig. 4. Hence, the electron experiences maximum attenuation. We might expect the radius to decrease approximately as $e^{-\alpha''\tau}$ where α'' is a positive number. Consequently, our assumed solution is

$$y = r_0 e^{-\alpha''\tau} \cos(\omega_c\tau + \omega_c t_1)$$
$$x = -r_0 e^{-\alpha''\tau} \sin(\omega_c\tau + \omega_c t_1).$$

By substituting these equations in (6) we find that equalities result for

$$\alpha'' = \frac{k_m}{B},$$

when

$$\alpha'' \ll \omega_c.$$

For the general case, we must assume that neither r_0' nor r_0'' is zero. The expected solution would be a superposition of the respective solutions for the preceding two cases, the portion of the equation associated with r_0' increasing as $e^{(k_m/B)\tau}$ and the portion associated with r_0'' decreasing as $e^{-(k_m/B)\tau}$. Hence, the assumed solution is

$$\begin{aligned} y &= r_0' e^{(k_m/B)\tau} \sin(\omega_c\tau + \omega_c t_1) \\ &\quad + r_0'' e^{-(k_m/B)\tau} \cos(\omega_c\tau + \omega_c t_1) \\ x &= r_0' e^{(k_m/B)\tau} \cos(\omega_c\tau + \omega_c t_1) \\ &\quad - r_0'' e^{-(k_m/B)\tau} \sin(\omega_c\tau + \omega_c t_1). \end{aligned} \tag{12}$$

That (12) is correct is easily demonstrated by substituting (12) in (6) and checking the equality. Equality results under the condition that

$$\frac{k_m}{B} \ll \omega_c.$$

As previously stated, this is the case of usual interest.

Consider further the solution for y. If the plates of the output coupler are parallel to the x axis, then it is the motion in the y direction which is important in inducing the signal from the beam to the coupler. By using the definitions of r_0' and r_0'' and by manipulating the terms of (12), we obtain

$$\begin{aligned} y = r_0 \Big\{ &\sin[\omega_c\tau + \omega t_1] \cosh \frac{k_m}{B}\tau \\ &+ \sin[\omega_c\tau + (2\omega_c - \omega)t_1] \sinh \frac{k_m}{B}\tau \Big\}. \end{aligned} \tag{13}$$

The electron remains within the quadrupole region for a time τ given by

$$\tau = \frac{L}{u_0},$$

where

L = the length of the quadrupole region.

Hence we have

$$\omega_c\tau = \frac{\omega_c}{u_0} L \equiv \beta_m L$$

and

$$\frac{k_m}{B}\tau = \frac{k_m}{Bu_0} L \equiv \alpha L,$$

where

β_m = the cyclotron wave number
α = the growth factor.

Using these definitions in (13) we have

$$\begin{aligned} y = r_0 \big\{ &\cosh \alpha L \sin[\omega t_1 + \beta_m L] \\ &+ \sinh \alpha L \sin[(2\omega_c - \omega)t_1 + \beta_m L] \big\}. \end{aligned} \tag{14}$$

Eq. (14) was derived specifically to apply to a single electron which enters the quadrupole region at $t = t_1$. We recognize that the equation applies to any electron of the whole train of electrons which make up the beam pattern. Each electron, of course, has a different t_1. Thus, by permitting t_1 to range through all values of time, (14) generates the y component of the beam position at the exit plane as a function of time.

A comparison of (14) with (8) shows that the signal is amplified by the factor cosh αL. In addition, an idler signal is generated at a frequency equal to the difference between the pump and the input signal frequencies. The idler signal has a magnitude proportional to sinh αL.

Experimental Results

The equations derived in the preceding section permit us to calculate the gain of a quadrupole amplifier. By inserting numerical values which correspond to a practical structure, one finds that substantial gain may be obtained with surprising ease.

According to (14), the gain is cosh αL, where $\alpha L = (k_m/Bu_0)L$. Eq. (3) defines k_m as $k_m = V_m/2d^2$, where V_m is the peak pump voltage applied across adjacent quadrupole elements as shown in Fig. 4, and d is the half spacing illustrated in Fig. 7. Thus,

$$\alpha L = \frac{V_m L}{2d^2 B u_0}. \tag{15}$$

Let us now insert the numbers which were selected for the first experimental model. The signal-and-cyclotron frequency was chosen to be 560 mc, corresponding to a magnetic field of 200 gauss (2×10^{-2} Webers per square meter). To keep the over-all dimensions of the tube small, a slow electron beam was used. It was known from previous experiments that a beam carrying about 50 micro-

amperes at less than 10 volts could be held to a diameter of about one-half millimeter in a 200 gauss field without difficulty. A velocity of $u_0 = 1.5 \cdot 10^6$ m/sec or 1/200 of light velocity was chosen corresponding to 6.25 volts accelerating potential.[18]

The transverse dimensions of the quadrupole structure were chosen large enough to allow ample clearance for the beam, since electron interception is highly undesirable in a low-noise tube. A spacing of 0.030 inch or 0.75 millimeter between opposite elements would have been sufficient from this standpoint. It was believed, however, that it would be advantageous to obtain a better approximation of a purely hyperbolic potential distribution in the beam region by keeping the quadrupole electrodes farther apart, and a spacing of 0.080 inch or 2 millimeters between opposite elements, corresponding to $d = 10 7_0$ meter, was chosen.

The axial length of the quadrupole structure was 0.4 inch or 1 cm; thus $L = 10^{-2}$ meter. For a 6-volt beam, this corresponds to a transit time of $6.7 \cdot 10^{-9}$ seconds, or nearly four cycles at the cyclotron frequency of 560 mc.

Substituting now the numerical values into (15), we find

$$\alpha L = \frac{V_m \cdot 10^{-2}}{2 \cdot 10^{-6} \cdot 2 \cdot 10^{-2} \cdot 1.5 \cdot 10^6} = \frac{V_m}{6}.$$

Thus, $\alpha L = 1$ for a pump voltage of as little as 6 volts peak-to-peak; with $V_m = 18$ volts, we obtain $\alpha L = 3$ and $\cosh \alpha L = 10$, corresponding to a gain of 20 db.

Very little pump power is required to maintain the quadrupole field. To obtain a rough estimate, let us assume the capacity between each pair of adjacent quadrupole elements to be 0.5 $\mu\mu$ farads; then at the pump frequency of 1120 mc, the circulating reactive power at $V_m = 18$ volts is about 2.3 volt-amperes, and if the capacity of the elements is tuned out by inductances having a Q of 100, the required driving power is 23 mw. Clearly, these figures do not represent an optimum design; they approximate the behavior of the early experimental models.

Fig. 8 schematically shows the arrangement of the input coupler, quadrupole and output coupler in the experimental tubes. The two Cuccia couplers are tuned to the center of the signal frequency band by built-in coils; balanced transmission lines with a characteristic impedance of about 300 ohms are connected to taps on the coils. These taps are positioned for good impedance match to the electron beam; signal source and output load are matched to the 300-ohm lines by adjustable impedance transformers. The total power loss in each coupler, including transmision lines and external transformer, ranges from 0.2 db at 400 mc to about 0.5 db at 800 mc. Improvement through better design appears quite possible, particularly at the higher frequency.

[18] The Brillouin flow current for a 6.25 volt beam of ½ millimeter diameter at 200 gauss is 90 microamperes.

The quadrupole structure is tuned to the pump frequency by means of four built-in coils interconnecting the four structural elements. To insure operation only in the desired π-mode (180° phase shift between adjacent elements), low-inductance straps are connected across opposite elements. Pump power is introduced into the quadrupole through a balanced two-wire line which ends in a single-turn loop closely coupled to one of the four coils.

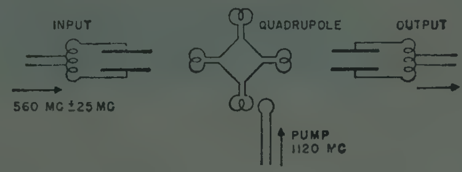

Fig. 8—Schematic diagram of first experimental quadrupole amplifier.

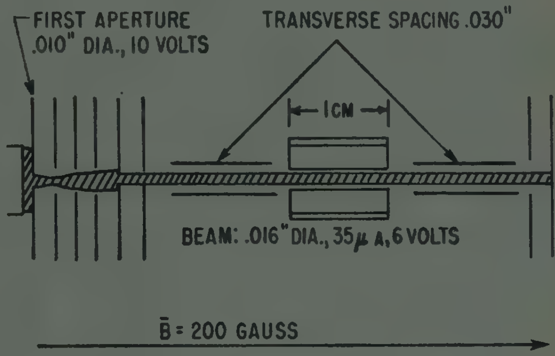

Fig. 9—Constructional features of experimental quadrupole amplifier.

Fig. 9 illustrates the construction of an experimental tube. The electron gun is designed to approximate Brillouin flow. The narrow aperture in the first electrode selects a very small cylindrical portion from the wide parallel stream emitted by the cathode. Next, this portion is made to converge violently, with the result that it diverges rapidly after passing a minimum radius in the vicinity of the second, highly positive electrode. The divergent beam is then gradually slowed down and bent parallel to the axis by the combined effect of the third and fourth apertures. Finally, marginal portions of the beam are sliced off by the last two apertures.

The entire gun is immersed in the same homogeneous magnetic field which serves to maintain the desired cyclotron frequency in the radio-frequency portion of the tube. Theoretically, Brillouin flow could be obtained if all electrons started from a single point on the cathode. The small aperture in the first electrode approximates such a point source.

A typical 560-mc tube (see Fig. 10) uses a beam current of about 35 microamperes. Because the magnetic field is proportional to the center frequency, correspondingly higher or lower beam currents are used at 800 and 400 mc.

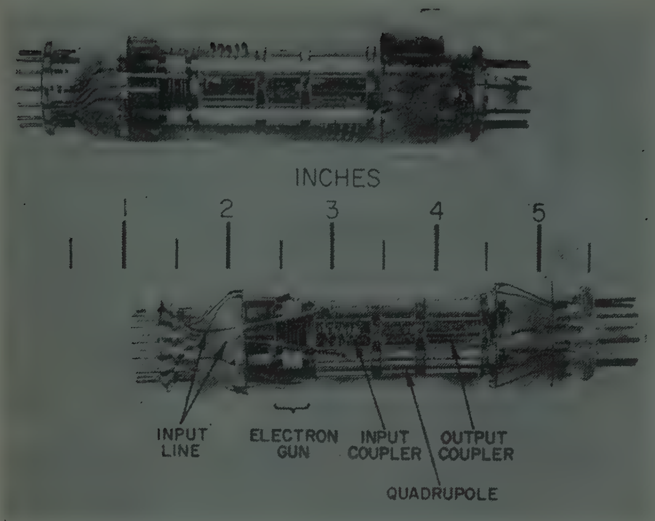

Fig. 10—Experimental quadrupole amplifiers, the lower one without glass envelope.

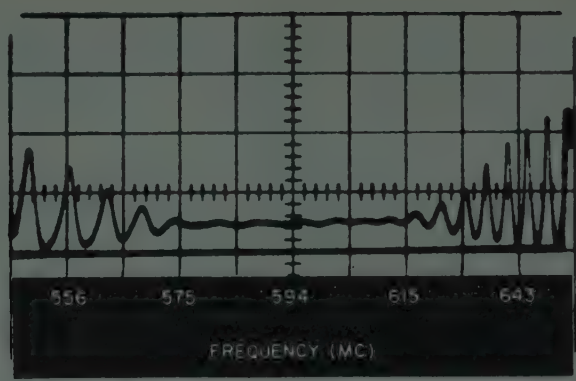

Fig. 11—Standing-wave ratio vs frequency at the input of a 600-mc quadrupole amplifier. Ordinate represents the square of the sum of incident and reflected voltage waves, measured at the sending end of a long 50-ohm line which is terminated at its receiving end by the input coupler.

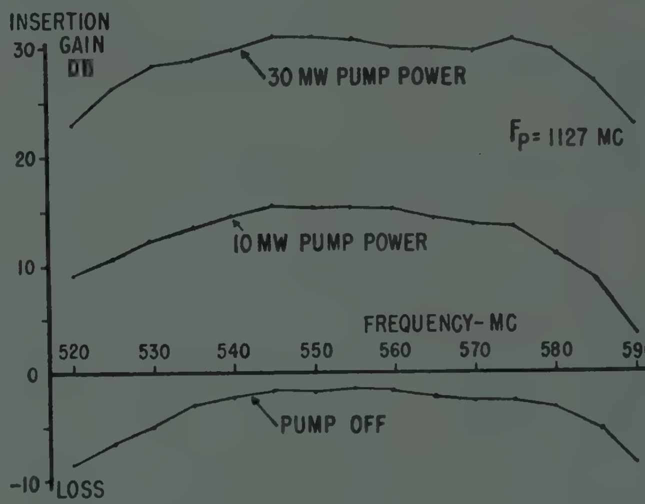

Fig. 12—Insertion gain of a 560-mc amplifier as a function of frequency, with pump power as a parameter.

When a tube is operated without pump power, it acts as a unidirectional transmission device or isolator; input and output couplers behave like loaded tuned circuits and may, by adding external reactances, be broad-banded to provide essentially resistive terminations over a band equal to about 8 per cent of the center frequency (see Fig. 11). Unidirectional signal transmission over this band is essentially flat. In addition to the coupler losses mentioned previously, some loss occurs in the signal transmission along the beam; this is not yet understood. Total insertion loss for tubes built to date varies from 0.8 db to 2 db.

When pump power is applied, gain is obtained in proportion. The increase in output signal level is the same regardless of signal frequency. This is clearly illustrated in Fig. 12. The lowest curve represents signal transmission with the pump turned off; there is an insertion loss of about 1.5 db which gradually increases toward the edges of the band. Application of pump power simply lifts the entire curve by 17 and 31 db, respectively; the amplification process is not frequency dependent and thus adds no selectivity.

The impedances of input and output coupler are in no way affected by the application of pump power. This is of great practical value; to take full advantage of the possibility of absorbing the fast-wave noise in the input coupler, the signal source must be matched to the input impedance of the coupler. This match, once accomplished, remains correct, regardless of the gain for which the pump power is adjusted.

With perfect input match, one might assume that all the fast-wave noise could be extracted from the beam. The noise figure of the tube, measured with a wide-band noise generator, should then be equal to the input coupler loss of 0.2 to 0.5 db. Measured noise figures are not that good; 1.5 to 1.6 db is measured regularly on good tubes, and 1.4 db is measured occasionally. Allowing for 0.4-db coupler loss, this leaves 1 db, or a noise temperature of about 70°K, unaccounted for. Similar to the signal loss along the beam mentioned previously, this is not yet understood.

Fig. 13 illustrates the behavior of the noise figure for an experimental tube with couplers tuned to 420 mc, broad-banded by appropriate coupling to tuned baluns outside the tube. The pump frequency was held at 840 mc and a receiver following the tube was tuned over the frequency range from 390 mc to 450 mc. Noise figures were determined by observing the power output from the receiver, with the input balun alternately connected to a 50-ohm resistance at room temperature and to a similar resistance immersed in liquid nitrogen.

In interpreting these noise figures, it is important to remember that we are dealing with a parametric amplifier which generates in its output two frequencies—signal and idler—for any given input signal frequency. Conversely, if the tube is followed by a receiver tuned to a given output signal frequency, there are two in-

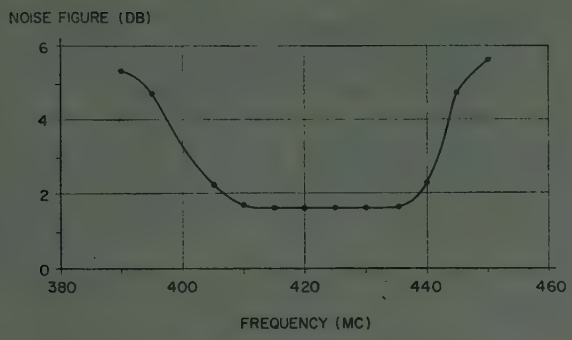

Fig. 13—Noise figure vs frequency for a 420-mc quadrupole amplifier.

put frequency channels—the signal channel and the idler channel—through which input noise may enter the receiver. Essentially, the parametric amplifier doubles the noise bandwidth of the receiver. This is observed as expected; in agreement with (14), receiver sensitivity on the two channels is essentially equal for tube gains higher than about 10 db. It is important to select the pump frequency so that the idler channel as well as the signal channel fall well within the pass band of the input coupler, allowing the beam noise on both channels to be absorbed by the signal source.

The noise figures quoted above were measured with noise generators broad enough to cover both signal and idler channels. They are valid without correction for applications which put both channels to use; radio astronomy is the best-known example. For use with single-channel signals, a correction must be made because of the noise generated in the idler channel. Where the idler and signal channels are substantially alike, as with the present quadrupole tubes, 3 db may be added to the broadband noise figure to obtain a single-channel noise figure. For example, 1.4 db would be increased to 4.4 db.

However, the performance of the amplifier under actual operating conditions can be much better than is suggested by such a noise figure. Most of the idler noise originates outside the tube; its magnitude, therefore, depends primarily on the temperature of the idler termination. Only when this termination is at room temperature will the performance be accurately indicated by the above single-channel noise figure. For the interesting case of an antenna having an equivalent source temperature of 100°K, the single-channel performance of the same amplifier (broad band $NF=1.4$ db) is equivalent to that of a conventional receiver whose noise figure is 3.24 db. With an antenna of only 50°K, the idler noise is reduced further and the single-channel performance becomes equal to that of a conventional receiver having a noise figure of only 2.86 db.

Conclusion

Low-noise electron beam parametric amplifiers employ a combination of two separate concepts. The first of these involves the use of the fast wave to carry signals along the beam. This makes possible the interchange of signal and noise in the input coupler, but it also prevents amplification by conventional methods which draw upon the dc energy of the beam. The second concept calls for the use of a nonhomogeneous alternating field to enhance the signal-induced motion of the electrons while they travel from input to output coupler.

In the quadrupole amplifier, we have selected the transverse cyclotron wave in preference to other types of electron waves. By choosing a cyclotron frequency close to the signal frequency, we obtain a fast cyclotron wave of nearly infinite phase velocity. This permits the use of lumped input and output couplers which are simple to build and easy to match. The quadrupole arrangement is specially suited for pumping the transverse cyclotron wave; again, because of the high phase velocity, a lumped quadrupole structure suffices.

Interaction between beam and metallic circuit, in the sense which this term has acquired in the traveling wave tube art, takes place only in the couplers. The growth process in the quadrupole is of a different nature: Here we have unilateral action of the pumping field on the moving electrons. The gain is calculated by tracing the path of individual electrons as they travel through the quadrupole, then averaging the over-all possible conditions of relative phase. Currents induced in the quadrupole by the moving electrons are of no significance.

The computation shows that high gain is easily obtained. Experimental tubes bear this out; they also demonstrate remarkably low noise, together with broad bandwidth and unconditional stability regardless of gain. They exhibit the idler frequency phenomenon characteristic of parametric devices.

The near-infinite phase velocity employed in these tubes represents a special case within a more general class of devices. Other tubes may be designed in which signal frequency and cyclotron frequency are quite different from each other, so that the phase velocity of the fast cyclotron wave is finite. Input and output couplers must then be adapted to this finite velocity. In most respects, such tubes will be quite similar to those described above.

It also appears possible to modify the geometry of the quadrupole in several different ways so as to permit the use of pump frequencies either lower or higher than twice the cyclotron frequency. A discussion of these variations would transcend the scope of this paper.

Generation of Harmonics and Subharmonics at Microwave Frequencies with *P-N* Junction Diodes*

D. LEENOV† AND A. UHLIR, JR.‡, ASSOCIATE MEMBER, IRE

Summary—The performances of a nonlinear resistance and a nonlinear capacitance in a broadband harmonic generator circuit are analyzed. The nonlinear capacitance is shown to have a considerably higher efficiency. Some results of harmonic and subharmonic generation experiments with a graded-junction silicon nonlinear capacitance diode are given.

Introduction

A SMALL, efficient harmonic generator has numerous applications at the present time. In connection with a transistor oscillator, it can be a source of microwave power; used with available generators it might generate significant power in the millimeter wave region. As another application, a harmonic generator can be used to multiply the output of a crystal stabilized oscillator to obtain a standard frequency in the microwave region. Similarly, a compact subharmonic generator operating at microwave frequencies would be desirable. It could be used to subdivide an atomic or molecular microwave resonant frequency to obtain a standard low frequency.

Semiconductor devices can perform both of these tasks and possess a number of advantages. They have small-size, low-power requirements, and ruggedness. Point-contact crystal rectifiers and welded-contact diodes have for some time been known to be effective harmonic generators. Studies of the efficiencies of these devices were reported upon in 1945–46 [1]. It was found that the welded contact diodes were superior to the rectifiers, up into the millimeter wave region, for generating the second or third harmonic. However, more recent work has shown that silicon point contact diodes are considerably better generators of high harmonics at millimeter and submillimeter frequencies [2], [3], [4].

Recently a diffused *p-n* junction silicon diode has been developed which acts as a voltage variable capacitance [5]. It has been named the "nonlinear capacitance diode." Tests have shown that this device is an unusually efficient harmonic generator.

In this paper, the use of semiconductor diodes for frequency multiplication and division is discussed. The existing theory of harmonic generation, as related to these devices, is reviewed briefly, and the calculation of the harmonic generation efficiency for a broadband circuit is presented. Following this is a collection of experimental results obtained with the nonlinear capacitance diode.

Review of Theory

In theoretical discussions of harmonic generation, two classes of nonlinear elements have been analyzed, nonlinear resistances and nonlinear reactances. The former group is exemplified by the point-contact rectifier, the latter by the recently developed nonlinear capacitance diode. The original welded-contact diodes developed and tested by H. North [1] were charge storage devices and hence behaved somewhat like nonlinear capacitors.

The theory of the nonlinear resistor as a frequency converter has been developed by C. H. Page [6] who gives an expression for the maximum harmonic generation efficiencies obtainable. His results are summarized in (1).

$$P_1 = P_0 + \sum_{n>1} P_n \geq \sum_{n>1} n^2 P_n \geq k^2 P_k \qquad \text{for any } k. \quad (1)$$

Here P_n represents the power developed at the nth harmonic, and P_1 represents the amount of fundamental power converted to other frequencies. From this we obtain the relations (2), for any particular value of n.

$$P_n \leq \frac{1}{n^2} P_1 \quad (2a)$$

$$P_0 \geq (n^2 - 1) P_n. \quad (2b)$$

Eq. (2a) states that even if all the fundamental power is converted, the efficiency for generating nth the harmonic cannot exceed $1/n^2$ when all other harmonics are absent. Eq. (2b) states that when the equality holds, the remaining fundamental power is converted to dc. If there is no dc loss, there is no harmonic generation.

On the other hand, greater efficiency might be expected from a nonlinear device which does not rectify, and hence does not convert any input power to dc. In their theory of frequency conversion by nonlinear reactances, Manley and Rowe [7] show that a lossless nonlinear capacitance as a harmonic generator can convert up to 100 per cent of the available generator power into any single harmonic, with proper tuning.

Another result obtained by Page is that a nonlinear resistor cannot generate subharmonics [6]. On the other hand, the theory of Manley and Rowe predicts that a nonlinear capacitance will generate subharmonics. These authors give relations which specify the power

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converted by a nonlinear reactance into sideband frequencies, when the device is driven by a beat oscillator (frequency b) and a signal generator (frequency s). Let us consider the case that the upper sideband and all harmonic images are reactively terminated, so that power is transferred only at the beat oscillator frequency b, the signal frequency s, and the lower sideband frequency $b-s$. Then the Manley-Rowe equations reduce to (3a) and (3b).

$$\frac{P_{b-s}}{b-s}+\frac{P_b}{b}=0 \tag{3a}$$

$$-\frac{P_{b-s}}{(b-s)}+\frac{P_s}{s}=0. \tag{3b}$$

By combining (3a) and (3b) we obtain (4):

$$-P_b = P_s + P_{b-s}. \tag{4}$$

This indicates that pump power is converted into power at two lower frequencies, s and $b-s$. Thus, if the device is terminated by resonant circuits tuned to these frequencies, a signal s, for example, can be amplified; this process is the basis of the varactor amplifier. With less circuit damping, spontaneous oscillations may be set up. In particular, if $s=b/2$, then $s=b-s$, and one resonant termination tuned to one-half the pump frequency should be readily excited. The one-third harmonic could be obtained with a termination (or terminations) resonating at frequencies $\frac{1}{3}b$ and $\frac{2}{3}b$. An infinite number of such examples can be chosen, of course, involving pairs of frequencies whose sum equals b. However, one would expect locking in to occur most readily for the lowest orders of subharmonics (one-half or one-third) since these frequencies when generated undergo harmonic generation, and the second or third harmonics would excite other resonant terminations of the circuit.

Broadband Analysis

In the previous section we discussed the theoretical upper limits of harmonic generation efficiency obtainable with nonlinear resistors and nonlinear capacitors. The superiority of the nonlinear capacitor was indicated. However, a better intuitive understanding of these nonlinear elements may be achieved through a study of broadband harmonic generation. This type of operation is analyzed in the present section.

A broadband harmonic generation circuit (resistive terminations at all frequencies) can be approximated experimentally and is not difficult to analyze. The efficiencies of a nonlinear resistor (N-R) and a nonlinear capacitor (N-C) are calculated below for this type of operation.

A further simplification is contained in the analysis. By way of explanation, we shall briefly discuss the way in which harmonic power depends upon fundamental power. In the range of very small applied voltages, the harmonic output increases faster than the first power of the fundamental input. With increasing input, the output climbs more slowly and eventually becomes proportional to the input. It is this limiting output efficiency, expressed as a conversion loss, that is calculated.

In the large voltage limit assumed for this calculation, the diodes are approximately ideal. The N-R diode is nearly a perfect rectifier, with an I-V characteristic given by Fig. 1. The N-C diode may be approximated by a device with infinite capacitance under forward bias, with complete recovery of charge when the voltage drops to zero, and with zero capacitance under reverse bias. The corresponding Q-V characteristic is also represented by Fig. 1. The equivalent circuit for broadband harmonic generation with an N-R diode or an N-C diode is shown in Fig. 2. The resulting current vs time relations, for the diodes under reverse bias, are illustrated in Fig. 3(a) and (b).

Fig. 1—Characteristic of ideal diodes.

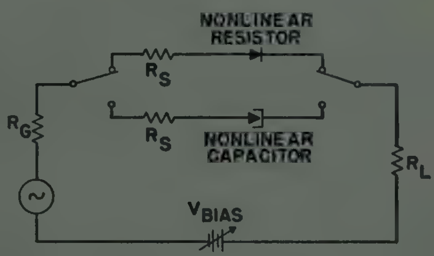
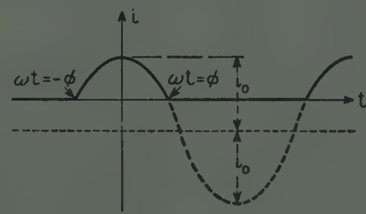
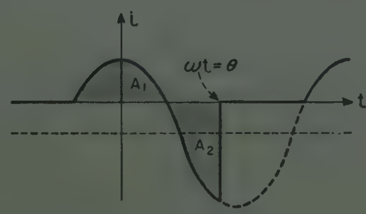


Fig. 2—Equivalent circuit of broadband harmonic generator.



(a)



(b)

Fig. 3—Current vs time curves for ideal diodes; (a) nonlinear resistor, (b) nonlinear capacitor.

Fig. 3(a) is the well-known rectifier characteristic. The dotted curve represents the current which would flow if the diode were absent; the displacement of the horizontal dotted line from the time axis is the effect of the reverse bias.

Fig. 3(b) represents the behavior of an ideal nonlinear capacitor. When the net applied voltage is in the forward direction, the device has a very large capacitance; hence negligible impedance, and the magnitude of the current is determined by the remaining circuit impedances. When the applied voltage is reversed, all of the charge which was stored during the forward part of the cycle is recovered; graphically this means that the area $A_2 = A_1$. At $\omega t = \theta$, the current drops discontinuously to zero. This discontinuity causes the curve in Fig. 3(b) to be richer in harmonics than that in Fig. 3(a).

The harmonic generation efficiencies are obtained from the Fourier amplitudes of the current vs time curves. The power absorbed by the load at a particular harmonic is readily calculated from the corresponding Fourier amplitude of current. The efficiencies are expressed as conversion losses, defined by (5).

$$L_n = 10 \log \frac{\text{available power from generator}}{\text{power output in } n\text{th harmonic}} \text{ (decibels)}. \quad (5)$$

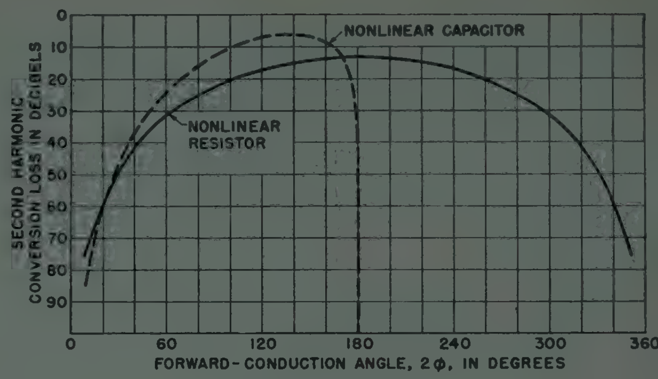
The conversion losses have been obtained as functions of bias voltage for a number of harmonics. Details of the calculation are given in the Appendix. In Fig. 4 several curves are presented of L_n vs the forward conduction angle, 2ϕ. This quantity is related to the bias voltage V_b by the equation $V_b = -V_0 \cos \phi$, where V_0 is the peak generator voltage.

In Fig. 4 we see that each curve for the nonlinear resistor has several peaks. Note that on these graphs the coordinate L_n increases in the downward direction. Thus the peaks represent maximum values of output, corresponding to minimum values of L_n.

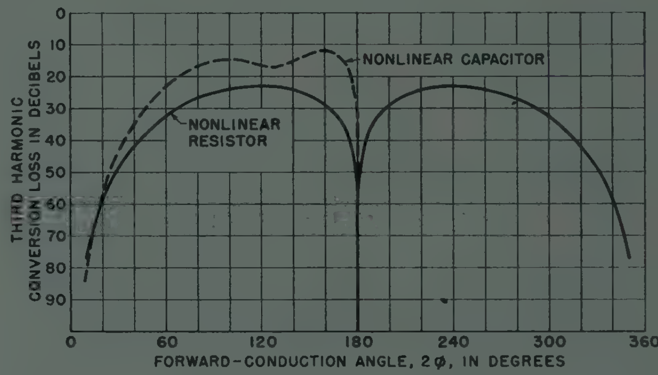
We see that in every case the number of relative minima of L_n is equal to $n-1$. In the Appendix this relation is proved analytically for all n. There it is shown that minimum values of L_n occur for $\phi = s\pi/n$, where s is any integer such that $1 \leq s \leq n-1$. We note that the first of these minima occurs when the forward condition angle $2\phi = 2\pi/n$. This means a relative maximum in output occurs when the duration of the forward current equals the period of the harmonic, an effect which would be expected intuitively.

In the case of the nonlinear capacitor, each curve also possesses $n-1$ humps (not necessarily maxima), but no general proof for such a relation has been developed because the expressions for L_n have not been obtained in closed form.

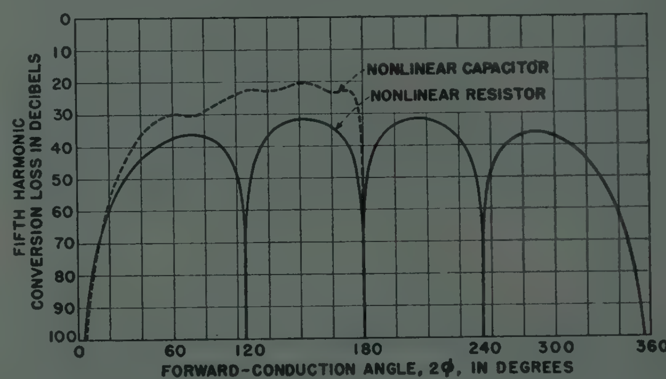
When diodes are operated so as to approximate the ideal behavior assumed above, the relation between the number of humps and the harmonic should provide a convenient means for identifying a particular harmon-



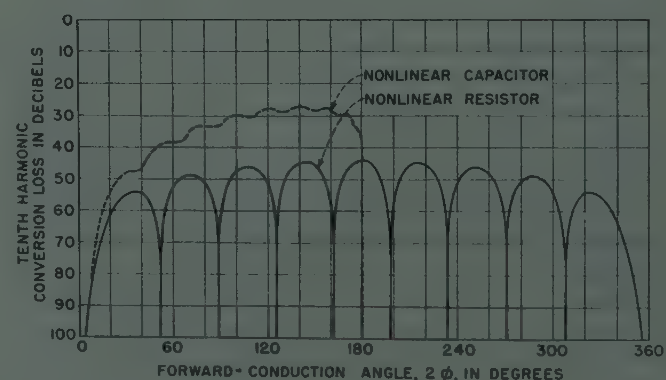
(a)



(b)



(c)



(d)

Fig. 4—Harmonic conversion loss vs forward-conduction angle for broadband operation.

ic, obtained from a broadband circuit and filtered from the rest of the output. The identification of the harmonic can then be obtained from an oscilloscope presentation of rectified power output vs bias voltage, when the latter is swept over an adequate range at a low frequency.

The minimum conversion loss for each harmonic is also of considerable interest. Values are given in Table I for a number of harmonics. (As noted previously, these results apply only in the limit of high drive.) To compare the N-C diode with the N-R diode, the difference between the corresponding conversion losses, expressed in db, is given for each harmonic in the column labeled "Advantage of N-C over N-R." The advantage in efficiency obtainable with an N-C diode is seen to increase for the higher harmonics.

The calculation of efficiencies discussed above applies only to ideal nonlinear elements. The parasitics of real diodes will cause their efficiencies to be diminished. A preliminary analysis for broadband operation has shown that the parasitics of the N-C diode should cause the efficiency to drop off rapidly as the output approaches a certain "cut-off" frequency f_c, where

$$f_c = \frac{1}{2\pi R_s C_{\min}}.$$

(Here R_s is the diode series resistance, assumed constant, and $C_{\min}$ is the smallest capacitance attainable, limited by the value of the breakdown voltage.) The cutoff effect is expected to become significant for output frequencies $f \cong 1/10\ f_c$, and to become large for $f \cong f_c$.

Description of Experiments

The silicon nonlinear capacitance diodes have been used to generate harmonics in broadband and tuned circuits, and also to generate the one-half harmonic. Representative results are given in Table II.

The broadband circuit used is shown in Fig. 5. The attenuators provide resistive terminations in conformity with the equivalent circuit in Fig. 2. The efficiencies at the second and third harmonics have been measured. On referring to the theoretical values for broadband (Table I), we see that the experimental values (Table II) were better than predicted for the ideal nonlinear resistor, but not nearly as high as predicted for the ideal nonlinear capacitor. This may have been due to the fact that wave shapes were not as sharp as in the ideal case. Deviations from the predicted values may also have been caused by circuit inductance and unaccounted losses. No power measurements were attempted in the experiments of multiplying 35 kmc, but the harmonic was identified from the shape of an oscilloscope trace of output power vs bias (see section on Broadband Analysis). It is also noteworthy that the trace obtained for the third harmonic was distinctly unsymmetrical. Thus its shape resembled the curve calculated for the nonlinear capacitor [Fig. 4(b)].

TABLE I

Limiting Conversion Losses for Ideal Diodes

$$\left[\text{Minimum } L_n - 10 \log \frac{R_g + R_s}{R_g}\right]$$

Harmonic	N-R Diode (db)	N-C Diode (db)	Advantage of N-C over N-R Diode (db)
2	13.5	9.2	4.3
3	23.2	15.1	8.1
4	27.5	18.5	9.0
5	32.0	20.4	11.6
6	34.7	22.6	12.1
7	37.7	24.2	13.5
8	39.9	25.7	14.2
9	41.9	26.4	15.5
10	43.8	27.3	16.5
100	83.9	47.9	36.0

TABLE II

Fundamental Frequency (mc)	Harmonic or Subharmonic Frequency (mc)	Conversion Loss (db)	Kind of Terminations
320	960	4.0	Tuned [8]
324	19,000	35	Tuned [9]
900	10,200	22.5	Tuned [9]
35,000	70,000	—	Broadband
35,000	105,000	—	Broadband
400	800	11	Broadband
300	900	19.7	Broadband
700	350	6	Tuned [10]

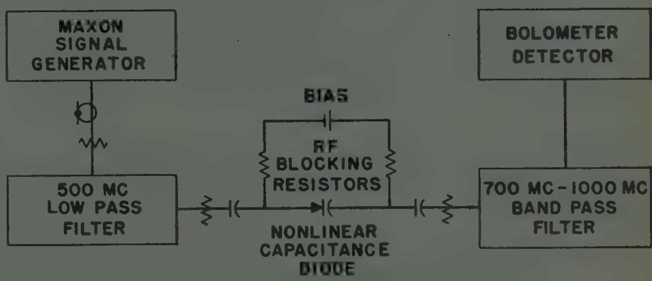


Fig. 5—Broadband harmonic generator.

The experiments performed under tuned conditions used either circuits similar to that in Fig. 5 with tuning elements replacing the pads, or resonant cavities tuned to the desired harmonic frequency. Unusually high harmonic yields were obtained in some of these experiments, exceeding the outputs to be expected from an ideal nonlinear capacitor in broadband operation, or from a tuned nonlinear resistor.

The generation of one-half harmonic by the junction diode is further evidence that the device is functioning essentially as a nonlinear capacitor, since this effect is not to be expected with a nonlinear resistor.

Conclusion

Theory indicates that a pure nonlinear capacitance should be superior to a nonlinear resistance for harmonic generation, when the characteristics of the two devices have the same degree of nonlinearity. It appears that

the welded contact diodes of North [1] were superior for generating low harmonics because of their nonlinear capacitance action. The recently developed diffused silicon diodes have been found to be quite efficient harmonic generators for obtaining frequencies up into the microwave region. This performance is due to their high "Q," or otherwise stated, their high "cut-off" frequency. Aside from their higher efficiency, the nonlinear capacitance diodes have a further advantage over point-contact rectifiers, in their greater power-handling capability and ruggedness.

At millimeter wave frequencies, the nonlinear capacitance diode harmonic generator, despite reduced efficiency, should still be superior to other sources of power. This is because the diode can be driven by a K-band klystron supplying considerable power at the fundamental frequency. The efficiencies obtained will be considerably smaller than predicted by the ideal theory, for two reasons: first, due to the cutoff effect described above; second, because the capacitance of the diode may be frequency dependent.

Appendix

Calculation of Conversion Loss

The conversion loss has been defined by

$$L_n = 10 \log \frac{\text{available power from generator}}{\text{power output in } n\text{th harmonic}} \text{ (in db)}. \qquad (5)$$

The available input power is defined as

$$P_{\text{in}} = \frac{V^2}{8R_G} \qquad (6)$$

where V is the peak generator voltage. The output power is given by (7).

$$P_{\text{out}} = \frac{1}{2} \frac{V^2}{(R_G + R_L + R_S)^2} (g_n^2 + h_n^2) R_L. \qquad (7)$$

Here g_n and h_n are, respectively, the coefficients of cos $n\omega t$ and sin $n\omega t$ in the Fourier expansion of the current waves in Fig. 3, assuming the dotted curves to be sine waves of unit amplitude. The actual amplitudes of the dotted curves are $V/(R_G+R_L+R_S)$.

On substituting (6) and (7) into (5), we obtain

$$L_n = 10 \log \frac{(R_G + R_L + R_S)^2}{4R_G R_L (g_n^2 + h_n^2)} \text{ (in db)}. \qquad (8)$$

We shall assume a matched load, $R_L = R_G + R_S$. For this case

$$L_n = 10 \log \frac{R_G + R_S}{R_G} - 10 \log (g_n^2 + h_n^2) \text{ (in db)}. \qquad (9)$$

To calculate L_n for the nonlinear resistor we refer to the current waveform in Fig. 3(a). We note that the current, being an even function of time, is representable by a cosine series. Then only g_n appears in (7), (8), and (9). For the case that the dotted sine wave has unit amplitude, the current is given by (10) for the interval $-\pi < \omega t < \pi$.

$$\begin{aligned} i &= \cos \omega t - \cos \phi & -\phi < \omega t < \phi \\ i &= 0 & |\omega t| > \phi. \end{aligned} \qquad (10)$$

The nth harmonic of this wave, g_n, is given by (11).

$$g_n = \frac{1}{\pi} \left[\frac{\sin (n-1)\phi}{n(n-1)} - \frac{\sin (n+1)\phi}{n(n+1)} \right]. \qquad (11)$$

The curves of L_n vs 2ϕ, plotted in Fig. 4, were calculated by substituting (11) into (9).

Using (11) it is possible to calculate the values of ϕ given relative maximum values of $|g_n|$, and hence maximum harmonic power output. These determine the relative minima of L_n, which are the peaks of the curves in Fig. 4. By differentiation, we find the condition for maximum $|g_n|$ to be given by (12):

$$\sin n\phi \sin \phi = 0$$

or

$$\phi = \frac{s\pi}{n} \qquad (12)$$

where s is any integer such that $1 \leq s \leq n-1$. Hence the function L_n (ϕ) should have $n-1$ minima in the range $0 < \phi < \pi$. As plotted in Fig. 4 these minimum values of L_n appear as peaks, to show that they correspond to maximum values of output.

The maximum values of $|g_n|$, obtained from (12), are given by (13). The one over-all

$$|(g_n)|_{\max} = \frac{2}{\pi} \frac{\sin (s\pi/n)}{n^2 - 1} \qquad (13)$$

maximum will occur when s/n approaches $\frac{1}{2}$: hence at $s = n/2$, n even; $s = (n-1)/2$ and $s = (n+1)/2$, n odd. From these, the minimum values of L_n are obtained, given by (14).

$$(L_n)_{\min} = 10 \log \frac{R_G + R_S}{R_G} - 20 \log \frac{2}{\pi} \frac{\sin [(n-1)\pi/2n]}{n^2 - 1} \text{ (db) } [n \text{ odd}]$$

$$(L_n)_{\min} = 10 \log \frac{R_G + R_S}{R_G} - 20 \log \frac{2}{\pi(n^2 - 1)} \text{ (db) } [n \text{ even}]. \qquad (14)$$

Values of $(L_n)_{\min}$ for several values of n, calculated from (14), are given in Table I.

The nonlinear capacitor current waveform is represented by Fig. 3(b). The equation for this current (again assuming unit amplitude for the dotted curve) is given by (15), for the interval $0 < \omega t < 2\pi$.

$$\begin{aligned} i &= \cos \omega t - \cos \phi & 0 < \omega t < \theta \\ i &= 0 & \theta < \omega t < 2\pi - \phi \\ i &= \cos \omega t - \cos \phi & 2\pi - \phi < \omega t < 2\pi. \end{aligned} \qquad (15)$$

The angle θ is determined in accordance with the assumption that the charge stored by the nonlinear capacitance during the interval of forward current, $-\phi < \omega t < \phi$, is completely recovered during the interval of reverse current, $\phi < \omega t < \theta$. This condition is expressed in (16) where

$$\int_{\omega t=-\phi}^{\omega t=\phi} i dt = -\int_{\omega t=\phi}^{\omega t=\theta} i dt \tag{16}$$

which is equivalent to (17).

$$\int_{-\phi}^{\theta} (\cos x - \cos \phi) dx = 0 \tag{17}$$

or

$$\sin \theta + \sin \phi - (\theta + \phi) \cos \phi = 0.$$

Solution of this transcendental equation gives values of θ corresponding to specified values of ϕ.

Having obtained numerical values of θ, the Fourier coefficients of the expansion of (15) may be calculated. Expressions for these are given in (18).

$$g_n = \frac{1}{\pi}\left[\frac{\sin (n+1)x}{2(n+1)} + \frac{\sin (n-1)x}{2(n-1)} - \frac{\cos \phi}{n} \sin nx\right]_{-\phi}^{\theta}$$

$$h_n = \frac{1}{\pi}\left[-\frac{\cos (n+1)x}{2(n+1)} - \frac{\cos (n-1)x}{2(n-1)} + \frac{\cos \phi}{n} \cos nx\right]_{-\phi}^{\theta}. \tag{18}$$

Values of L_n as a function of ϕ are obtained by substituting the results of (18) into (9). Since θ is the solution of a transcendental equation, L_n is not expressed in closed form, and no analytic expressions for $(L_n)_{\min}$ are available. Therefore the minimum conversion losses given in Table I were obtained directly from the numerical results.

The numerical solutions for the nonlinear capacitor are readily obtained with an electronic computer. All the calculations described above were performed on the IBM 650 Magnetic Drum Calculator.

Acknowledgment

We wish to thank the several authors for permission to quote their measurements prior to publication.

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Comparison and Evaluation of Cesium Atomic Beam Frequency Standards*

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Summary—**Cesium atomic beam frequency standards of different design have been compared, and the principal sources of errors in these devices have been studied. The unresolved discrepancy found between the standards was about 2 parts in 10^{10}. The characteristics of the standard, sources of errors, and the details of the comparison tests are discussed in this paper.**

Introduction

For many years the most accurate of all physical measurements has been that of frequency, and its practical applications have kept pace with the technique. Atomic standards have provided a major advance in the reproducibility and stability of frequency references, so that it has become important to examine their performance critically.

Investigation [1] of an atomic beam standard at the National Physical Laboratory (NPL), Teddington, England, led to the conclusion that it could be used to calibrate[1] quartz oscillators in terms of the natural resonance frequency of cesium (at zero magnetic field) to 1 part in 10^{10}. Similar work at the National Company, Malden, Mass., established that their atomic beam standards, which are called Atomichrons®, agreed with one another to 3 in 10^{10}.

The two atomic beam standards were compared by means of transatlantic radio transmissions. The frequencies of the phase-stable transmissions from MSF (60 kc) and GBR (16 kc), Rugby, England, were measured at Teddington in terms of the NPL standard, and at Harvard by J. A. Pierce in terms of a local quartz oscillator, which in turn was compared by means of another stable transmission with an Atomichron in Camden, N. Y. [2]. The comparisons indicated that there was probably an average systematic difference (NPL-Atomichron) = 4 parts in 10^{10}. Other comparisons of time signals related to the two standards, made by Dr. William Markowitz of the Naval Observatory, indicated a larger discrepancy. It clearly became important, therefore, to make a more direct comparison. This was emphasized by both the International Committee of Weights and Measures and the International Scientific Radio Union. The comparison, made since at Teddington, is described here. The results are given briefly in *Nature* [3].

Principle of Operation

Before the tests are described in detail, a brief review of the principle of operation of the atomic frequency standards is presented. As the name implies, the frequency produced or measured by an atomic standard is uniquely related to a time-invariant resonance of an atom—in this case to the magnetic field-insensitive resonance in cesium 133. The atomic beam tube is the device used to compare the frequency of an external RF generator with that of the cesium. Fig. 1 illustrates the atomic beam tube schematically. The tube functions in the following manner. A beam of neutral cesium atoms effuses from the source, with thermal velocities of about 200 meters/sec. An atom in the beam will proceed in a straight line until it is acted on by the inhomogeneous magnetic field of a deflecting magnet, or until it strikes and is absorbed by an obstacle or the walls of the beam tube. The pressure in the tube must be low enough so that scattering of the beam is negligible. The source, deflecting magnets, and detector are arranged so that only a certain class of the atoms emitted from the source may reach the detector. The atoms which reach the collector undergo a transition in the region between the deflecting magnets. The transition, which amounts physically to a rearrangement of the internal structure of the atom, will be induced only when the atom is irradiated with an RF signal having a frequency nearly equal to that of the atomic resonance. At other frequencies the RF signal has no effect.

If an atom undergoes a transition, it will be deflected in the second magnet so that it will follow the path to the collector, where it is converted to an ion and ultimately to an electric current. If the atom does not undergo a transition, it will follow the path which misses the collector. Hence, the presence of beam current at the detector indicates that transitions are induced, which in turn means that the frequency of the RF signal applied to the beam is very close to the atomic resonance frequency.

If the frequency of the RF generator is swept slowly through the resonance frequency, and the detector beam

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[1] The accuracy of the calibration procedure mentioned above merely expresses how well the ratio (the number of oscillations of a quartz oscillator in a given interval of time/number of oscillations made by a cesium atom over the same interval of time) is known. The accuracy to which the cesium resonance frequency is known in terms of the traditional astronomical standard of time does not enter here.

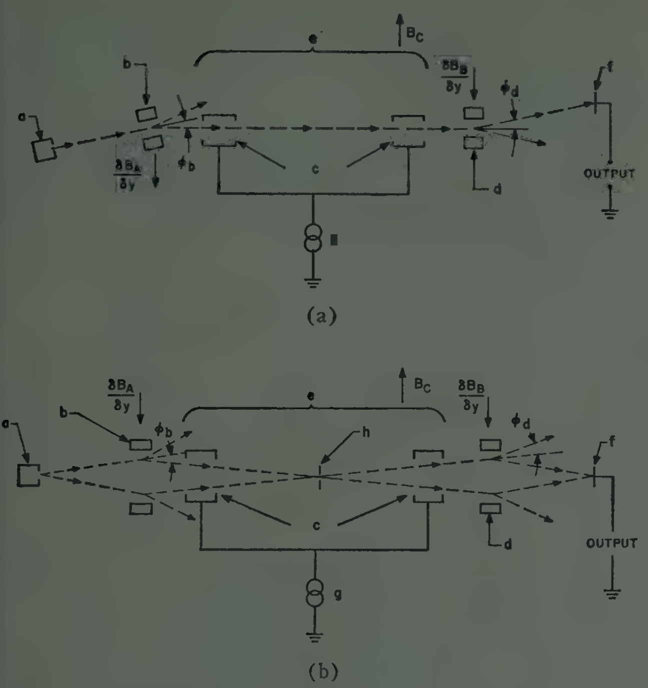

Fig. 1—Path of atoms through magnetic fields. (a) Atomichron. (b) NPL. The deflection angle is ϕ_d which in practice is very small, a typical value being 10^{-2} radian. a = source. b = "A" magnet, strong inhomogeneous magnetic field; c = RF cavities; d = "B" magnet, strong inhomogeneous field; e = weak dc field; f = ionizer collector; g = RF generator 9192 mc; h = slit.

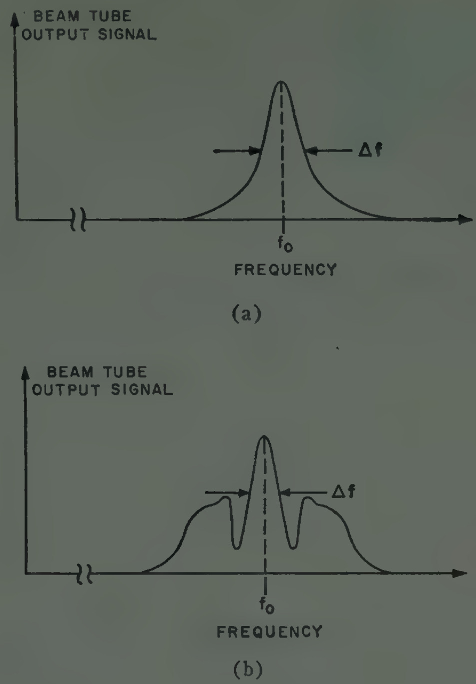

Fig. 2—Resonance curves; (a) Rabi method, (b) Ramsey method.

current is plotted as a function of the generator frequency, the result will be as shown in Fig. 2(a), if a single RF cavity is used to irradiate the beam (the Rabi method), or as in Fig. 2(b), if two separated cavities are used (the Ramsey method). The center frequencies of both patterns will be equal to the atomic resonance frequency provided no distortions are present. The full width of the resonance between the points of half the maximum amplitude is 120 cps for the Atomichron and 330 cps for the NPL tube, and the nominal center frequency is 9192.631830 mc, the unit of time being the second of UT2 in June, 1955 [4]. The line width in cps is given approximately by $1/T$, where T is the time in seconds that an atom of average velocity spends in the space between the two cavities.

A complete exposition of the theory of the atomic beam tube, the cesium resonance, and the interaction between the RF fields and the atoms can be found in ref. [5].

Principal Differences in Construction of the Two Standards

Beam Path

In the Atomichrons the detector is placed so that it is reached only by atoms which have been deflected in one direction [Fig. 1(a)], whereas in the NPL tube atoms in both parts of the beam are detected. This necessitates the use of a central slit [Fig. 1(b)].

Beam Tube RF Structure

Both the NPL tube and the Atomichrons use the Ramsey method of separated cavities to stimulate the transitions, but the waveguide structures are of different design (Fig. 3). The ideal waveguide structure for use with the Ramsey method should have uniform oscillating fields of equal amplitude, which are in phase in the two regions where the beam is exposed to the RF. The structures of Fig. 3(a) and 3(c) can most closely approximate this ideal. The structure in Fig. 3(b), in addition to exposing the beam to the cavity fields, exposes it to that in the feed guides, where the maximum oscillating field amplitude is about one-fourth that in the cavities. An analysis of this structure has shown it to be satisfactory, provided the electrical lengths of the feed guides, the cavity tunings, and field distributions are correct.

Generation of the RF Signal

The NPL system generates the cesium resonance frequency by multiplying the frequency of a crystal oscillator which operates at a subharmonic of the cesium frequency in the neighborhood of 5 mc. In the Atomichron, the cesium frequency is generated from a crystal oscillator which runs at exactly 5 mc,[2] so that a considerable amount of synthesizing is required. As a result, the spectrum applied to the beam tube in the Atomichron is not as free of undesirable sidebands as the NPL system.

[2] As a matter of practical convenience, the cesium frequency at zero magnetic field has been defined to be 9192.631840 mc in the Atomichrons. The difference between this value and the value in use at NPL (ref. [4]) has been allowed for in the data processing.

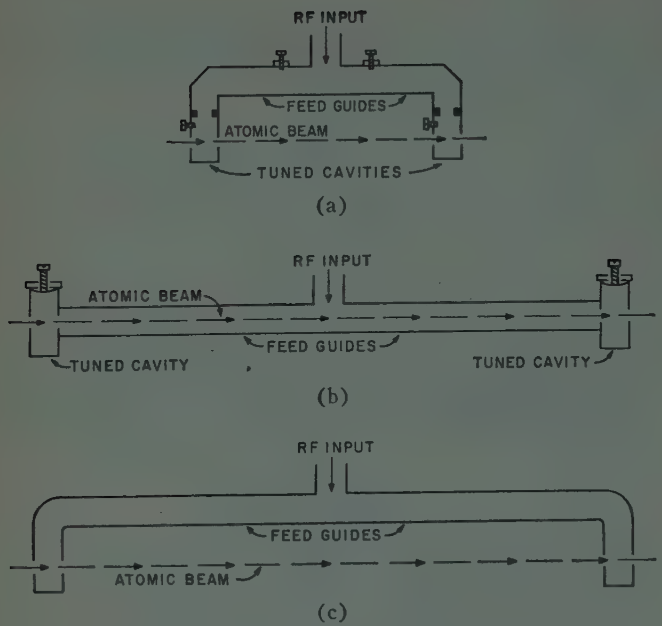

Fig. 3—(a) NPL RF section, (b) standard Atomichron RF section, (c) experimental Atomichron RF section.

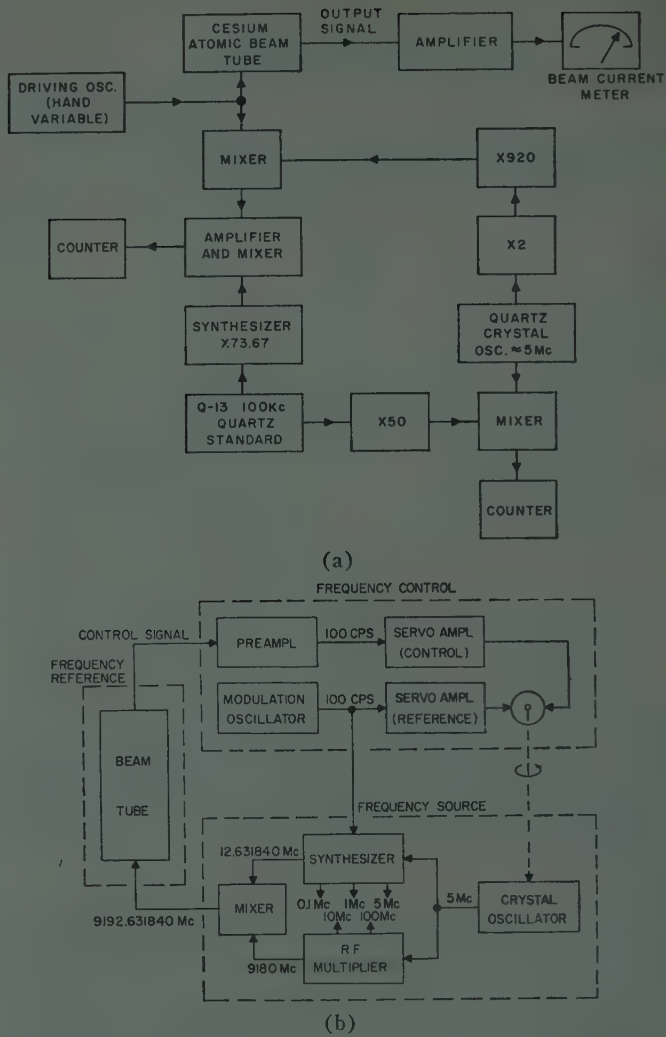

Fig. 4—(a) Block diagram of NPL system, (b) Atomichron block diagram.

Servo Control

There is no provision in the NPL system for locking the crystal oscillator to a subharmonic of the cesium frequency. The oscillator is tuned manually to study the resonance. Hence, the cesium tube is used as a resonator to calibrate a crystal standard. The Atomichron crystal oscillator is locked, through a servo system, to a frequency uniquely related to the cesium frequency. The system block diagrams are shown in Fig. 4.

Frequency Distortions

The term "distortion" is used to describe anything which can cause the frequency of an atomic standard to be different from the atomic resonance frequency. The most important distortions are listed in the following paragraphs.

Magnetic Field

The frequency of the field-insensitive cesium transition is given by [5]

$$f = f_0 + 427\ B^2 \tag{1}$$

where

f_0 = frequency at zero field ($0.919263183 \times 10^{10}$ cps),
B = magnetic field in gauss,
f = cesium resonance frequency in cps at a field of B gauss.

For various reasons, it is not possible to operate at zero field. NPL operates at 0.043 gauss and the Atomichrons at 0.060 gauss. The standards are, therefore, offset from the zero field frequency by 0.77 and 1.54 cps respectively. Hence, the magnetic field in the transition region must be carefully measured and controlled if accuracies exceeding 1 part in 10^9 are required. The field is measured by observation of a field-sensitive resonance in cesium, so that an accurate, internally consistent field determination is achieved.

Relative Cavity Phase

In the separated-oscillating field technique employed, any lack of synchronism between the two oscillating fields will cause a distortion in the observed resonance. The shift in the frequency of the peak of the resonance is given by

$$\delta f_\phi = \frac{\delta\phi}{180} W \tag{2}$$

where

δf_ϕ = shift of peak frequency in cps,
$\delta\phi$ = phase shift between oscillating fields in degrees,
W = width of the resonance at half maximum amplitude in cps.

The presence of a phase shift can be detected by observation of the symmetry of the resonance curve; perfect symmetry is obtained only when the phase shift is

zero. The amount of asymmetry caused by a given phase shift depends on the velocity distribution of the beam which reaches the detector; this distribution is in general substantially different from the beam-velocity distribution directly in front of the source. A calculation of asymmetry as a function of phase shift was made through the use of a velocity distribution calculated for the Atomichron at the detector. The equation relating asymmetry to phase shift is [6]

$$\delta\phi = 3.2S \tag{3}$$

(Require $SS < 2\%$ for applicability of Eq. 3)

where

$\delta\phi$ = phase shift in degrees,
S = percentage asymmetry, as defined from Fig. 5.

Through the combined use of (2) and (3), the frequency error arising from cavity phase shifts can be estimated from the characteristics of the observed resonance. Unfortunately, cavity phase shifts are not the only source of asymmetry in the curve. Thus, in order to measure the cavity phase-shift effect through the symmetry measurement, one must have the guarantee that there are no other sources of distortion in the system. This is not entirely possible with the standard Atomichron RF structure [see Fig. 3(b)], because some of the RF fields between the cavities can conceivably contribute to an asymmetry. In this paper the slight asymmetry found to be present is treated as if it had arisen solely from cavity phase shift, and an appropriate correction is applied.

Another approximation made in the application of this correction is that the beam-velocity distribution is assumed to be the calculated one. There is also a mathematical effect where a modulated signal is used to study the resonance curve. In this case the resonance frequency is determined by the criterion that the amplitude of the fundamental component of the output signal equals zero. When the curve is asymmetrical, this does not result in the same determination of the resonance frequency as given by the peak of the dc curve obtained with a nonmodulated RF signal. A calculation indicates that the shift of the zero crossing (modulated case) is roughly two-thirds the shift of the peak of the dc curve. The estimated accuracy of the correction is included in later tables containing the experimental results.

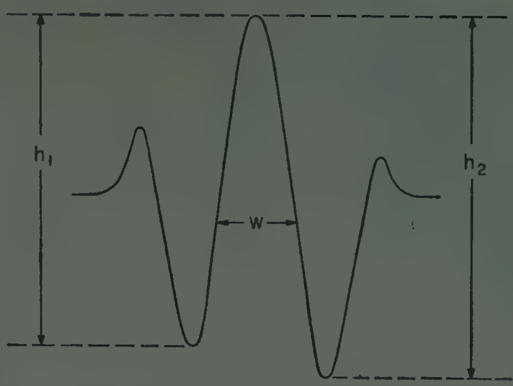

Fig. 5—Asymmetric resonance due to cavity phase error.

$$S = \frac{h_2 - h_1}{\frac{1}{2}(h_2 + h_1)} \times 100$$

$$\delta\phi = 3.2S \text{ (Degrees)}$$

$$\delta f_\phi = \frac{\delta\phi}{180} W$$

RF Sidebands

Any sidebands not symmetrical about the cesium frequency will cause a frequency shift.

This problem has not been completely analyzed. Therefore, experimental measurements have been made on both the NPL tube and the Atomichron. The NPL results are reported in ref. [1].

In these experiments a single sideband of controlled amplitude and frequency was added to the RF signal driving the beam tube. The results on an Atomichron for a sideband with a frequency (f_s) 200 kc away from the cesium frequency (f_0) obey an equation of the form:

$$f_r - f_0 = \frac{\alpha(P_s/P_0)}{f_0 - f_s} \tag{4}$$

where

f_r is the observed resonance frequency, and α is a constant equal to 1.5×10^4 (cps)^2,
P_s/P_0 = ratio of sideband power to optimum power at f_0.

When the sideband is in the frequency range of the neighboring transitions, the frequency shifts do not obey such a simple equation and must be plotted experimentally.

Distortions Arising from Frequency Modulation of the RF

This class of distortions is associated only with the Atomichron, since the NPL system does not use frequency modulation. There are two results of interest. The first is that the use of FM does not in itself introduce any symmetry distortion. However, if there is second-harmonic distortion on the FM, there may be an attendant frequency shift. The shift, which has been calculated for a single velocity beam, is given by

$$f_r - f_0 \approx \left[0.45 \sin\phi \cos\left(\frac{\omega_m T}{2}\right)\right] HW \tag{5a}$$

when the RF signal is in the form

$$E_{RF} = \cos\{\omega t - K[\cos\omega_m t + H\cos(2\omega_m t + \phi)]\}. \tag{5b}$$

It is assumed that K is adjusted to its normal operating value. In the above equations the notation is:

$100\ H$ = percentage 2nd harmonic distortion on the modulation,
ω_m = modulation frequency,
T = time atom spends between RF cavities,
W = full width of resonance at half max. amplitude (cps),
ϕ = angle between first and second harmonic modulation.

From (5a) it is evident that, in any case:

$$|f_r - f_0| < 0.45HW. \tag{5c}$$

When a second harmonic distortion of controlled amplitude and phase was injected into an Atomichron, the maximum frequency shift observed was about half that given by the right-hand side of (5c). The dependence of the shift on $\sin\phi$ was verified.

There are probably other sources of distortion, but it is believed that those listed above are the major ones.

Details of Test Carried out at NPL

Standard Comparison Procedure

The tests carried out at NPL may be divided into two classes—those which compared the Atomichrons under standard operating conditions with the NPL system and those which sought to measure the sources of difference in the systems. The experimental arrangement for the first class of tests is shown in Fig. 6. It can be shown that

$$\frac{f_{c0} - f_{n0}}{f_{n0}} = \frac{f_m - 1160 - \delta_c + \delta_n + 0.18}{f_{n0}} \tag{6}$$

where

f_{n0} = cesium zero field frequency as measured by the NPL system,
f_{c0} = cesium zero field frequency as measured by an Atomichron,
δ_n = offset from zero field frequency due to the magnetic field in the NPL system,

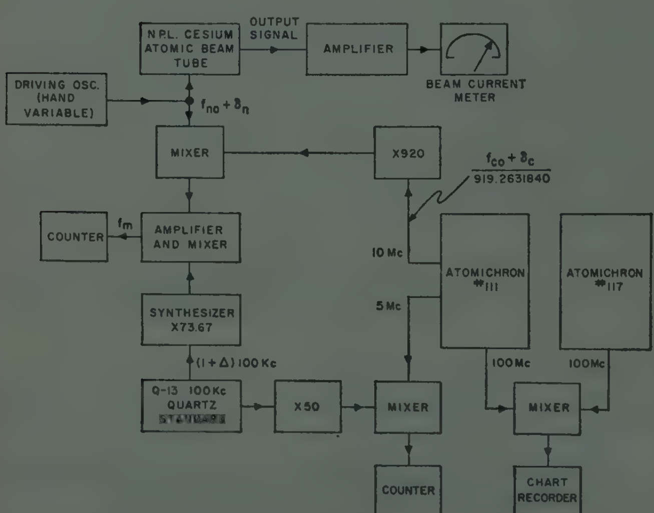

Fig. 6—Block diagram for frequency comparison tests.

δ_c = offset from zero field frequency due to the magnetic field in the Atomichrons,
f_m = measured audio frequency,
Δ = the deviation of the Q^{13} oscillator from nominal [taken as 2.5 parts in 10^8 in (6)].

The data obtained from the standard comparison tests are given in Table I. In this table the Atomichrons are identified by their serial numbers; the 857X1 experimental tube was used with the electronic system of the No. 111 Atomichron. For all the data of March 12 and thereafter, the Atomichrons underwent a basic alignment before comparison. This consisted of having the critical electronic controls misadjusted, then having different operators realign the system according to a standard procedure. This practice was intended to show up any frequency dependence due to system adjustment.

Distortion Measurements

The asymmetry of the resonance was measured on all the beam tubes, with the use of RF without modulation. The RF signal from the NPL electronics was studied and found to yield a very pure note at X band, and since any sideband effects should be negligible with only 5-mc sidebands, the NPL electronics was selected to drive all the beam tubes for the asymmetry measurements. It was assumed that any observed asymmetry was due to a beam-tube effect.

If a beam tube were to exhibit an asymmetrical resonance, it would be expected that the asymmetry would be a function of RF power and that the center of the resonance would shift with the RF power. This phenomenon is referred to as the power shift. With the use of nonmodulated RF, both the asymmetry and the resonance frequency were measured as a function of power. The results of these measurements are applied in Table II as corrections to the data from Table I. The power shift associated with asymmetric resonance curves is caused by the variation of the velocity distribution function with power.

Proceeding on the assumption that the NPL electronics were not causing any distortions, those performing the tests sought a measure of the distortions associated with the Atomichron RF signal and servo control. First, the normal closed-loop operating frequencies of the Atomichrons were compared with open loop frequencies, with NPL electronics driving the Atomichron beam tubes. The tubes ran consistently lower with the NPL electronics. This is referred to as the "electronic effect," and the measurement results are listed and applied as corrections in Table II. To complete the experiment, the NPL beam tube was driven, open loop and without modulation, with the electronics of the No. 117 Atomichron system. In this case, the NPL tube ran 0.8 part in 10^{10} higher than it did with its own electronics. This series of measurements was not sufficient to determine how much of the "electronic effect"

in the Atomichrons was contributed by the various elements in the electronics; only the total effect was determined. Any attempt to isolate the effects is complicated by the fact that the resonance curve widths of the NPL system and Atomichron systems are different.

Discussion of Results

After the corrections inferred from the distortion measurements have been applied to the data of Table I, one would expect the corrected results to show the Atomichrons and NPL system to agree. The discrepancy in the corrected results is not well understood at present. It may be due partially to the approximate nature of the asymmetry correction.

While the comparisons were being carried out at NPL, the transatlantic frequency measurement programs, carried on by Prof. J. A. Pierce at Harvard and Dr. W. Markowitz at the U. S. Naval Observatory in collaboration with NRL, were active. The Atomichron at Harvard had been carefully measured against those which were shipped to NPL, just before they left. The data accumulated should supply definitive information on the accuracy of transatlantic frequency measurements.

TABLE I

FREQUENCY REPRODUCIBILITY AFTER REALIGNMENT

UNIT 1×10^{-10}

Date 1958		Frequency Difference			
		111-NPL	117-NPL	857X1-NPL	Q13-NPL
March	6	3.6	3.5		230.0
	7	3.8	3.6		231.8
	10		3.3		233.5
	11		4.0		233.6
	12		3.2	4.7	234.5
	14		2.5	4.2	235.3
	17	4.1	3.5		238.2
	18 (A.M.)	3.7	3.7		239.4
	18 (P.M.)	3.6	2.7		238.1
	19 (A.M.)	4.3	3.3		240.2
	19 (P.M.)	4.0	3.2		240.0
	20 (A.M.)	3.9	3.1		240.7
	20 (P.M.)	4.5			241.4
	24 (A.M.)	3.5	3.4		244.7
	24 (P.M.)	3.6	2.8		244.8
	24 (P.M.)	3.8	3.3		245.5
	26	3.4			244.1
	28	3.2			245.8
April	1 (A.M.)	3.5	3.0		249.2
	1 (P.M.)	3.7	2.9		249.6
	2	3.5	3.2		250.7
Mean		3.7±0.3	3.2±0.4	4.5±0.3	

TABLE II

BEAM TUBES TESTED AS RESONATORS

UNIT 1×10^{-11}

Effect	Frequency Error			
	111	117	857X1	NPL
Servo and electronics	+8±4	+6±4	+20±4	0
Asymmetry	−2±9	−11±9	0±7	−10±10

The measured errors due to the servo, electronics and asymmetry can legitimately be applied as corrections to the mean frequencies of Table I, and the corrected results of the comparison are as follows:

111-NPL	$2.1 \pm 1.4 \times 10^{-10}$
117-NPL	$2.7 \pm 1.4 \times 10^{-10}$
857X1-NPL	$1.5 \pm 1.4 \times 10^{-10}$.

SUBSEQUENT MEASUREMENTS

J. V. L. Parry, one of the authors of this paper, has continued to make weekly basic alignments, measurements and comparison. The results are compiled in Table III. The limits given to the average values are slightly higher than those of Table I because of a small systematic change in the relative values of the Atomichrons and the NPL standard. Since the changes are little more than the standard deviation of a single observation, it is not possible to say definitely when they occurred, but the value of 111-NPL appears to have decreased gradually, whereas that of 117–NPL appears

TABLE III

UNIT 1×10^{-10}

		Atomichron No. 111-NPL Standard	Atomichron No. 117-NPL Standard
April	8	3.6	3.0
	9	2.8	—
	14	1.8	2.4
	15	1.9	2.3
	28	1.7	2.1
May	5	4.1	3.4
	12	3.7	3.0
	19	3.0	3.1
	27	3.4	3.4
	29	3.9	3.7
June	2	3.5	3.0
	9	3.3	—
	16	3.2	—
	23	3.9	3.9
	27	3.5	3.5
July	1	3.3	3.4
	4	3.4	3.0
	7	3.4	3.0
	14	2.6	2.6
	15	3.5	3.5
	21	3.0	2.7
	25	3.0	2.9
August	11	2.2	2.5
	18	3.2	—
	26	3.7	—
	27 (A.M.)	3.5	2.8
	27 (P.M.)	3.0	—
	28 (A.M.)	2.0	2.5
	28 (P.M.)	2.0	2.5
September	1	2.5	3.0
	2 (A.M.)	2.0	3.1
	2 (P.M.)	2.5	3.5
	3 (A.M.)	2.6	3.7
	3 (P.M.)	1.7	2.7
	5 (A.M.)	2.5	4.2
	5 (P.M.)	2.7	—
	15	2.7	—
	22	2.0	—
	24	1.5	1.9
	29	1.7	—
October	30	0.2	—
November	3	−0.8	0.2
Mean of all results from March to November		3.1±0.8	3.1±0.5

to have changed rather suddenly in September, 1958. It might be mentioned that by November 18, 1958, the operational time of 111 was 1036 hours and that of 117 was 662 hours.

In August, 1958, changes were made to the NPL standard with the object of eliminating the asymmetry recorded in Table II. A new cavity system, shown in Fig. 7, was designed, with provision for the sensitive adjustment of the relative phases in the two cavities. The phase bridge arm was an odd number of half-wavelengths long and was adjusted to resonance at the cesium frequency. It was coupled to both cavities through very small holes, and the signal was observed at a detector in the middle. When the phases at A and B are equal there is a minimum signal, and the setting to the minimum was found to be extremely sharp.

The new system gave a symmetrical resonance, as nearly as could be judged experimentally, and for a time both the new and old systems were used to find a statistical value for the frequency difference. The value found was -1.7×10^{-10}. Since August 26, 1958, only the new system has been used, but the values in Table III have been adjusted to correspond to the initial condition of the NPL standard.

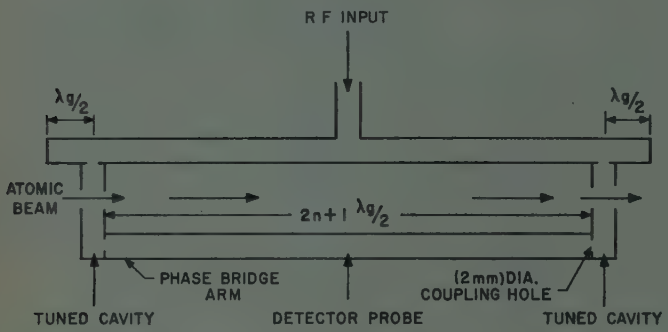

Fig. 7—New NPL RF section.

Through the use of the mean values for the whole period of the comparisons, together with the new measured value of the asymmetry error of the NPL standard in place of that given in Table II, the following final results were achieved:

$$111\text{-NPL} \quad 0.8 \pm 1.5 \times 10^{-10}$$

$$117\text{-NPL} \quad 1.9 \pm 1.5 \times 10^{-10}.$$

Acknowledgment

The work was carried out at the Natl. Phys. Lab. and the results are published by permission of the Director. The Atomichrons and support for the Natl. Co. effort in this program were made available by the U. S. Army Signal Res. and Dev. Lab. under contract number DA-36-039 SC-74863. The cooperation of all the agencies involved is gratefully acknowledged.

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[3] L. Essen, J. V. L. Parry, J. H. Holloway, W. A. Mainberger, F. H. Reder and G. M. R. Winkler, "Comparison of caesium frequency standards of different construction," *Nature*, vol. 182, pp. 41–42; July 5, 1958.
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[5] N. F. Ramsey, "Molecular Beams," Oxford University Press, New York, N. Y., pp. 115–144; 1956.
[6] C. W. Franklin, private communication.

Pattern Detection and Recognition*

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Summary—**Two types of pattern-processing problems are discussed in this paper. The first, termed "pattern detection," consists of examining an arbitrary set of figures and selecting those having some specified form. The second problem, "pattern recognition," consists of identifying a given figure which is known to belong to one of a finite set of classes. This is the problem encountered when reading alphanumeric characters.**

Both recognition and detection have been successfully carried out on an IBM 704 computer which was programmed to simulate a spatial computer[1] (a stored-program machine comprised of a master control unit directing a network of logical modules). One of the programs tested consisted of a recognition process for reading hand-lettered sans-serif alphanumeric characters. This process permits large variations in the size, shape, and proportions of the input figures and can tolerate random noise when it is well scattered in small specks.

Programs for detecting L-shaped (or A-shaped) figures in the presence of other randomly drawn patterns have also been successfully tested.

I. Introduction

A PRINCIPAL goal of the research upon which this report is based is to determine how machines can be made to duplicate some of the remarkable feats that humans perform daily when dealing with visual images. For example:

1) Presented with a new coloring book, a five-year-old child quickly points out all outlines of dogs.
2) A post-office clerk deciphers the name of a city in a carelessly written address.
3) A hold-up victim selects a photograph of his assailant from among the collection in police files.
4) A frequent visitor to an art museum identifies the creator of a newly acquired painting merely from its general appearance and style, and the knowledge that it was done by one of the better known nineteenth-century artists.

Examples 1 and 3 illustrate what we shall term *pattern detection*. This is the process of examining a set of figures and selecting those that fall into some particular class of patterns, defined as the *target set*. Examples 2 and 4 involve a different kind of operation, which we shall define as *pattern recognition*. Here a single input pattern known to belong to one of several known classes is to be identified. In other words, the problem is to specify which of a finite number of labels should be attached to the input. Thus, in example 2, the postal clerk knew that the scrawled word that he was trying to decipher was the name of one of the cities in the state of New Jersey, and his object was to decide *which* one. Compare this with the detection problem of example 1. Here, the child was required to search through an assortment of patterns selected from an unlimited ensemble and to indicate which, if any, were pictures of dogs. Note that detection subsumes recognition in that any recognition problem can be treated as a finite number of detection problems. The converse is not true.

Both detection and recognition will be discussed here in some detail with alphanumeric characters being used as the patterns of interest. Systems have been devised and successfully tested for accomplishing the following:

1) Recognizing any given hand-printed alphanumeric character.
2) Examining an input field consisting of a set of randomly drawn patterns and detecting all L-shaped figures that are present. (A-shaped figures have also been detected.)

The above-mentioned systems consist of programs written for the spatial computer.[1] A brief description of this machine (abbreviated SPAC) follows, and a somewhat more detailed description including the order structure, is included in an appendix.

SPAC consists of a rectangular network of logical modules directed by a master control unit. Each module has direct contact with its four immediate neighbors (Fig. 1) and reeeives orders from the master control, which issues identical commands to all modules in the network.

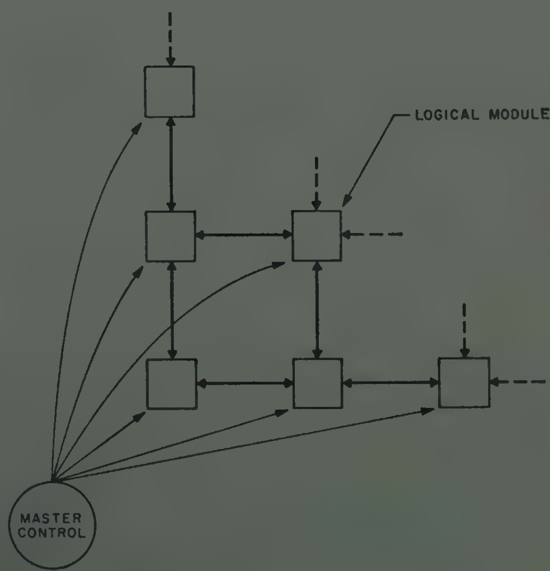

Fig. 1—Structure of spatial computer.

* Original manuscript received by the IRE, April 30, 1959; revised manuscript received, May 9, 1959.
† Bell Telephone Laboratories, Inc., Whippany, N. J.
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A module consists of some logical circuitry, a one-bit principal register (PR), and a set of one-bit memory registers (MR's) individually addressable as MR1, MR2, etc. (In the original description of SPAC,[1] the PR's are called accumulators.) A pattern can be stored in the PR's or in any of the MR arrays.

The master control includes a random-access memory for storing instructions, an instruction counter, and decoding circuitry. It operates like the control unit of a conventional digital computer, reading instructions out of memory in sequence, decoding them and sending appropriate control signals out on a set of buses feeding the modules.

The SPAC programs that will be discussed here were tested by means of a simulation program on an IBM 704 Computer. The simulated SPAC has a 36×36 array of modules, and there are nine MR's per module.

Important work in the pattern processing area has been done by Selfridge[2,3] and Dinneen[4] who performed a number of interesting experiments on a digital computer which indicated that much could be accomplished through the use of a small number of very elementary operations, such as local averaging, spatial differentiation, and blob counting. Their primary goal was to investigate the learning process and they were not concerned with finding efficient recognition or detection procedures.

Kirsch[5] and some of his colleagues at the Bureau of Standards have made use of the SEAC computer to study various pattern processing operations. Their objective was to develop a library of computer subroutines that might be useful in pattern processing. In addition to operations similar to those used by Selfridge and Dinneen, the Bureau of Standards group has demonstrated some interesting properties of an operation in which patterns are alternately complemented and spatially differentiated. No effort was made to develop specific recognition or detection systems.

A report by Greanias *et al.*[6] describes a system for recognizing members of a sixteen character alphabet (numerals and some miscellaneous printer symbols). The system has been tested via a computer program and has successfully identified samples of printed characters in the presence of background noise. As described in the paper, this method does not permit variations in the size and proportions of the input characters.

[2] O. G. Selfridge, "Pattern recognition and learning," Symp. on Information Theory, London, Eng.; 1955.

[3] O. G. Selfridge, "Pattern recognition and modern computers," *1955 Proc. WJCC*, pp. 91–93.

[4] G. T. Dinneen, "Programing pattern recognition," *1955 Proc. WJCC*, pp. 94–100.

[5] R. A. Kirsch, L. C. Ray, L. Cahn and G. H. Urban, "Experiments in processing pictorial information with a digital computer," *1957 Proc. EJCC*, pp. 221–230.

[6] E. C. Greanias, *et al.*, "Design of logic for recognition of printed characters by simulation," *IBM J.*, vol. 1, pp. 8–18; January, 1957.

T. L. Dimond[7] has developed a process for reading hand-printed numerals, provided that they are drawn in accordance with certain constraints that restrict size, proportion, and location.

The Solartron electronic reading automaton,[8] produced commercially in England, can read 120 printed numerals per second. Only small variations in size and style are permissible.

The amount of work being done on pattern processing problems is increasing too rapidly to permit a complete review of the field, but the preceding summary represents a reasonable cross section.

II. The Effects of Quantizing Patterns on a Grid

We shall not consider multi-color patterns or those represented in half-tones. The original inputs will be assumed to be representable in black and white.

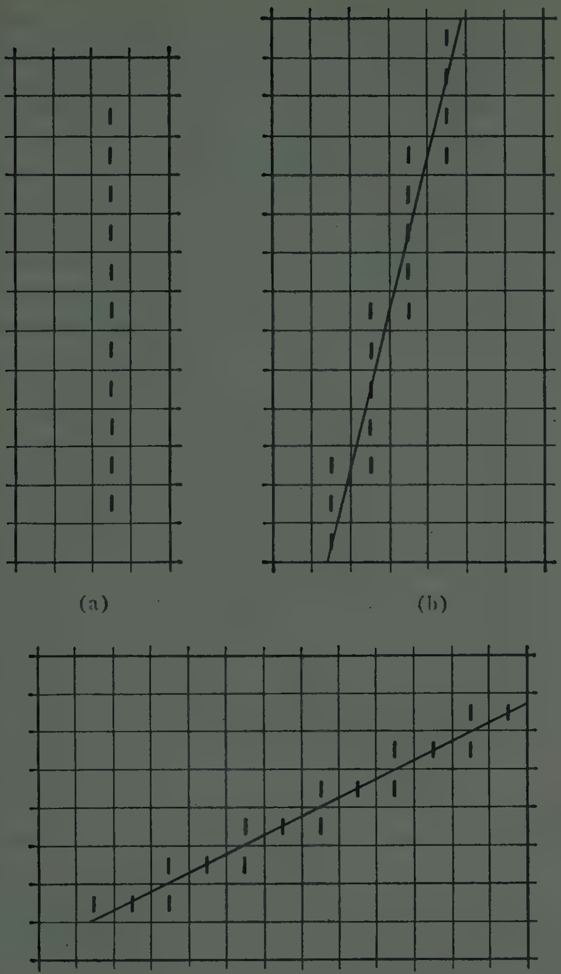
As a first step in processing patterns, it is desirable to reduce the input field to a discrete form. This can be done by superimposing a grid or matrix of squares over the figure (assumed to be black on white) and placing a one in each square if the black area within that square exceeds a certain threshold. Zeros are filled in elsewhere (although zero-cells will usually be left blank in the diagrams). All of our input fields will be of this form.

Such a quantizing process (which can be physically realized by devices such as flying spot scanners) results in a loss of information concerning the original pattern, but this loss can always be reduced by decreasing the mesh of the grid (that is, by increasing the number of squares per unit area). If the grid is too coarse, certain details of the pattern will be lost. This effect can sometimes be made to serve a useful function in filtering out insignificant irregularities that might cause confusion. For example, if a character printed by a typewriter is magnified by a factor of several thousand diameters and projected on a screen it is generally somewhat difficult to identify because of the apparently random distribution of tiny blobs of ink on the paper. Thus, for a given input field, there is a limit on the amount of useful grid resolution.

Regardless of how fine a grid is used, there are still important transformations which occur when a continuous line is mapped onto a discrete grid. Assume that the threshold is set so that a one is placed in every cell touched by any portion of a black area. A straight vertical line will be mapped as a set of one-cells (squares with ones in them) one above the other, as shown in Fig. 2(a). Except for the change in thickness, if the one cells are blacked in the resulting picture will be the same as the original line.

[7] T. L. Dimond, "Devices for reading handwritten characters," *1957 Proc. EJCC*, pp. 232–237.

[8] "Typed figures translated into computer code," *Engineering*, vol. 183, pp. 348–349; March 15, 1957.



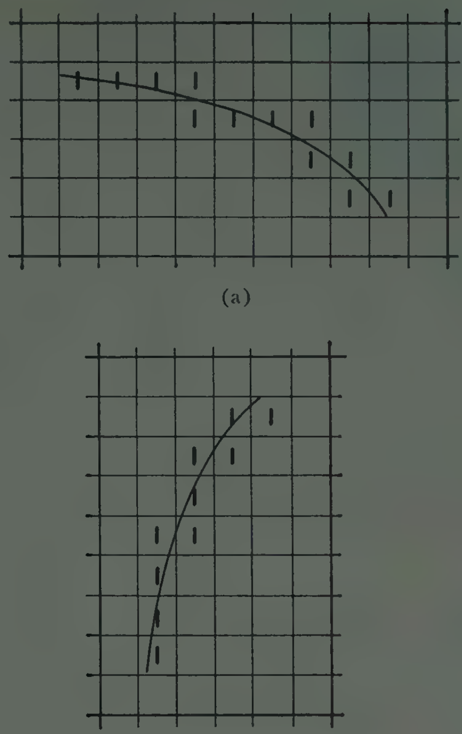
(a) (b)

(c)

Fig. 2—Mappings of straight lines on a grid.

Consider now the mapping of a straight line whose slope exceeds unity, but is not infinite [Fig. 2(b)]. Such a map must have slope discontinuities, since the edges of the array of squares in the map must be either vertical or horizontal at all points. Thus, a map of a line with a slope anywhere between $+1$ and ∞ consists of a chain of vertical strips, with the top cell of each strip to the left of the bottom cell of the strip above. The numbers of cells in the strips corresponding to a particular straight line differ from one another by at most one (except for the uppermost and lowermost strips which may have fewer cells), and are approximately equal to the slope. Lines with absolute slopes less than one (lines closer to being horizontal) are similarly mapped into chains of overlapping horizontal strips, as shown in Fig. 2(c). In such cases, the number of one-cells per strip approximates the inverse slope of the line.

If a line is not quite straight, its map will still be qualitatively as above. The difference will show up in the form of variations in the lengths of some of the strips.



(a)

(b)

Fig. 3—Mappings of curved lines on a grid.

The mapping of a curved line onto a discrete matrix can be thought of as the union of a set of maps derived from a series of nearly straight line segments approximating the curve. A more precise approach is suggested by an examination of Fig. 3(a), a mapping of a section of a curve that is convex upward. Note that the lengths of the horizontal strips that constitute the mapping decrease monotonically from the top down. In other words, the map consists of a staircase in which every step is as long as, or longer than, the step below.

Fig. 3(b) is a map of a curve convex to the left, with slope between $+\infty$ and $+1$. Here the lengths of the vertical strips decrease monotonically to the right. This monotonicity property can be used to characterize the curvatures of given lines.

III. Smoothing

It is important that any system for pattern detection or recognition be relatively insensitive to minor irregularities in the input fields. Interchanging zeros for ones in a few isolated cells should not cause significant changes in the output of a pattern processing system. As was pointed out previously, some smoothing is achieved merely by quantizing the input. This however is not adequate, and in some cases the quantization itself introduces irregularities.

There are at least two basic approaches to this problem. One is to carry out a preliminary smoothing opera-

tion on the input fields prior to the main task. Another approach is to incorporate the smoothing into the basic recognition or detection operations by making them insensitive to variations confined to any small area. Both of these techniques are used in the programs that will be described here.

The explicit smoothing process,

1) Fills in isolated holes in otherwise black areas,
2) Fills in small notches in straight edge segments,
3) Eliminates isolated ones,
4) Eliminates small bumps along straight edge segments,
5) Replaces missing corner points (under certain conditions).

Fig. 4 shows a cell x, and the eight cells around it. Treat each cell as a binary variable. That is, $b=1$ if cell b contains a one and $b=0$ if cell b contains a zero.

$$\boxed{\begin{array}{ccc} a & b & c \\ d & x & e \\ f & g & h \end{array}}$$

Fig. 4—Points involved in smoothing operations.

The first step in the smoothing operation places a one in x if the Boolean function $f_1=x+bg(d+e)+de(b+g)$ is unity. (That is, x is changed from zero to one if three of the four variables b, d, e, and f are ones.) If this process is carried out simultaneously for every cell in the matrix, then steps 1 and 2 will be accomplished. (In the preceding sentence, "simultaneously" means that the next state of each cell is determined before any of the other cells have been changed.)

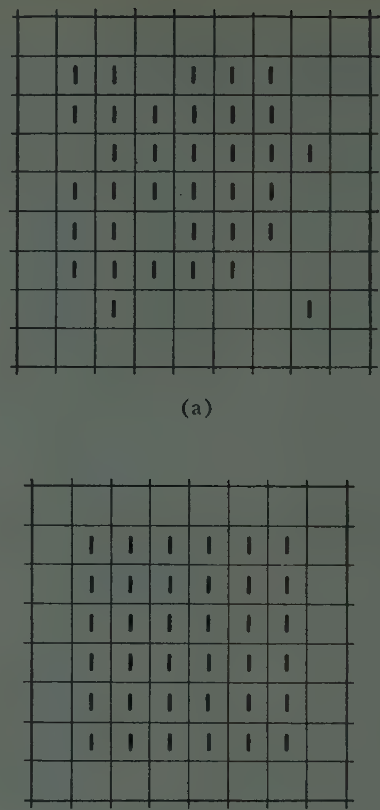
Steps 3 and 4 can be accomplished by replacing the contents of each cell x with $f_2=x[(a+b+d)(e+g+h)+(b+c+e)(d+f+g)]$. A series of four more operations of a similar nature serve to carry out step 5. The smoothing will transform Fig. 5(a) into Fig. 5(b).

About one hundred SPAC orders (each executed once) are required to accomplish the preceding operations.

A simple 25-step subroutine which closes breaks in lines, if the gaps are no wider than one unit, can be inserted ahead of the above described smoothing routine.

These programs will clean up only small noise "specks" affecting isolated cells or in some cases pairs of cells. However, smoothing operations for eliminating larger irregularities might be devised by considering larger regions around each cell and exploiting continuity properties.

Note that the smoothing operations discussed thus far are size dependent in an absolute sense. That is, the irregularities are smoothed out on the basis of absolute size, not on the basis of size relative to that of the over-all figure.



(a)

(b)

Fig. 5—Effects of smoothing.

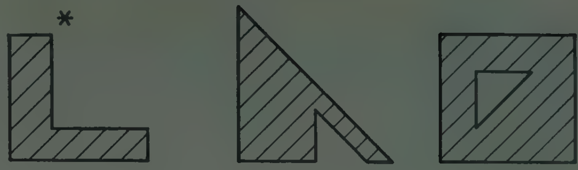
This situation is satisfactory only if the figures being processed do not vary in size by more than a factor of two or three in magnitude. If wider variations are to be permitted in the sizes of the input figures, then it would be necessary to insert parameters in the smoothing programs which would be functions of some dimension of the input figure, such as the over-all height. A preliminary part of the program would then measure this dimension and insert appropriate parameters in the smoothing program. These parameters would control the sizes of the irregularities to be smoothed out. All of this is doubteless possible, but it would add considerable complexity to the program. Possibly, the way to avoid the necessity for such an approach would be to use some sort of analog controlled lens system that would keep the sizes of input figures within a range of two or three to one.

IV. Edge Sequences

In order to be able to detect patterns in the sense defined in the introduction, it is necessary to be able to state precisely, for any target set, just what characteristics distinguish this set from all others. For most interesting target sets these characteristics must be independent of size, location, and, to a considerable extent, of the proportions of component parts.

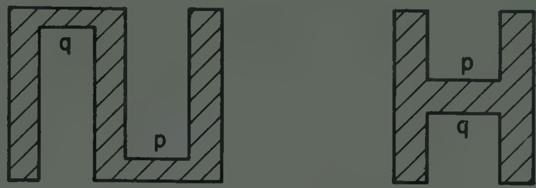
An important property which goes far toward satisfying these requirements will now be introduced.

Consider the letter "L" in Fig. 6(a) (regarding it as a figure covering a non-zero area, not as a pair of intersecting line segments). Beginning at the starred corner and proceeding in a counter-clockwise direction along the edges (boundaries) of the figure, the following succession of edges is found: top, left, bottom, right, top, right. This sequence, abbreviated at TLBRTR (T for top, L for left, etc.), is cyclic, and if another starting point is used, then an equivalent form such as BRTRTL will be found. Such a sequence, which will be referred to as an *edge sequence*, is not affected by changes in size, proportion, or location.



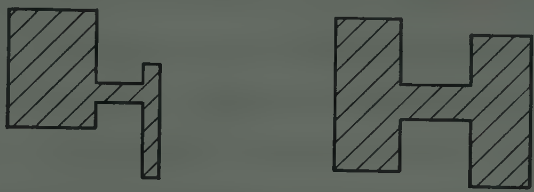
(a) (b) (c)

Fig. 6—Illustrating the use of edge sequences.



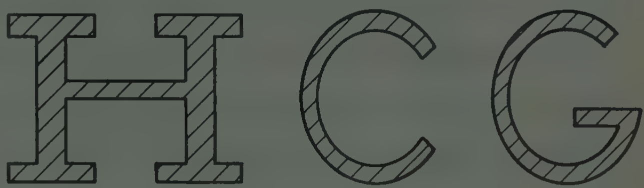
(a) (b)

Fig. 7—Limitations of edge sequence description.



(a) (b)

Fig. 8—Variations in proportion.



(a) (b) (c)

Fig. 9—Serifs.

The edge sequence of Fig. 6(b) is LBR (BL) B (TR), where (BL) and (TR) represent diagonal edges facing "bottom-leftward" and "top-rightward" respectively. Similar notation can be devised for curved edges.

In the case of a figure with a hole, such as is shown in Fig. 6(c), two edge sequences are required for a description; one for the outside, and one for the inside. For this case they are LBRT and R (TL) B, respectively.

Edge sequences constitute a powerful tool for pattern detection. As will be shown in a later section, the ideas concerning edges that were introduced earlier can be utilized by a machine to find the figures in a given input field that have edge sequences corresponding to the target set.

Edge sequences alone are not in general sufficient to completely characterize many interesting target sets. A particular edge sequence may, for example, be a necessary condition for membership in some target set, but there may be other requirements as well. Consider for example Fig. 7(a). This figure has the same edge sequence as a certain alphabetic character drawn in block capital form without serifs. But few readers would classify this figure as an H, although both (a) and (b) of Fig. 7 share the same edge sequence. An additional constraint that must be satisfied before a figure can be classified with 7(b) as an "H" is that the edge labelled p in Fig. 7(b) be directly above the edge labelled q. This condition is not satisfied by the corresponding edges in Fig. 7(a). Such "relative-edge-position" tests are frequently necessary after the edge sequence requirement has been met.

Questions of proportion may also arise. For example, it would be reasonable to exclude Fig. 8(a) from the H-set, while admitting Fig. 8(b). Both have the appropriate edge sequences and their edges are in the proper relation to one another. It is difficult to specify precisely which figures intermediate between the pair in Fig. 8 should be considered as acceptable H's. However, an arbitrary set of standards may be chosen for each target set, such as the requirement (as applied to the present example): "the width of the wider leg must not exceed twice the width of the narrower leg." The research reported on here has not yielded any more specific results concerning this aspect of the problem.

Still another question is posed by Fig. 9(a). Is this a respectable member of the H-set previously discussed? At first, the results of a lifetime of conditioning would lead one to immediately answer "yes." But, on second thought, it becomes obvious that the form of Fig. 9(a) is certainly significantly different from that of a block capital H without serifs, which is the target set under discussion [see Fig. 7(b)]. Only long established custom decrees that this is also an "H," and it would be perfectly possible to devise an alphabet in which the two forms represented different letters. The difference between Fig. 9(b) and Fig. 9(c) is of the same nature, and is smaller in magnitude than the difference between the two H's, and yet one is called a "C," and the other a "G."

Thus, it may be convenient to think of certain target sets as being *compound;* that is to say, of being composed of the union of two or more simpler sets. Just as it would not be wise to expect a single description to suffice for both a small "h" and a capital "H," it is similarly unreasonable to expect the same description to cover different styles of capital "H"'s.

Note that this argument holds only for the detection problem. Where pattern recognition is involved, it may well be feasible to devise (for example) a single scheme which can indicate that both forms of the capital "H" are sufficiently different from all other members of the alphabet as to be definitely classed as "H"'s.

V. Pattern Detection

In this section it will be shown how the ideas previously introduced can be utilized for the purposes of pattern detection. A SPAC program for detecting L-shaped figures will be presented and discussed in order to illustrate the principles involved. (The Appendix and an article mentioned previously[1] describe SPAC.)

The L-detection program has been executed successfully on an IBM 704 computer programmed to simulate SPAC. In order to make perfectly clear what the L-

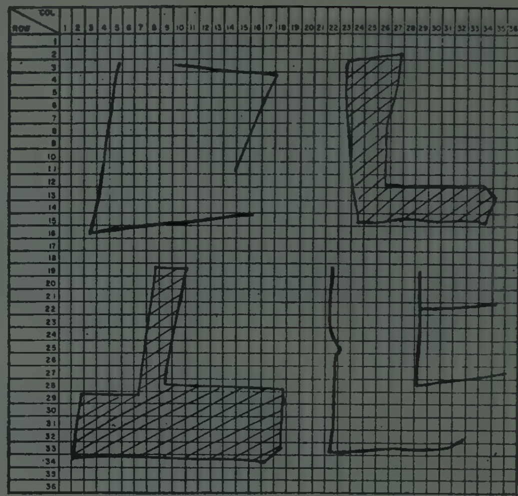


Fig. 10—Original drawing.

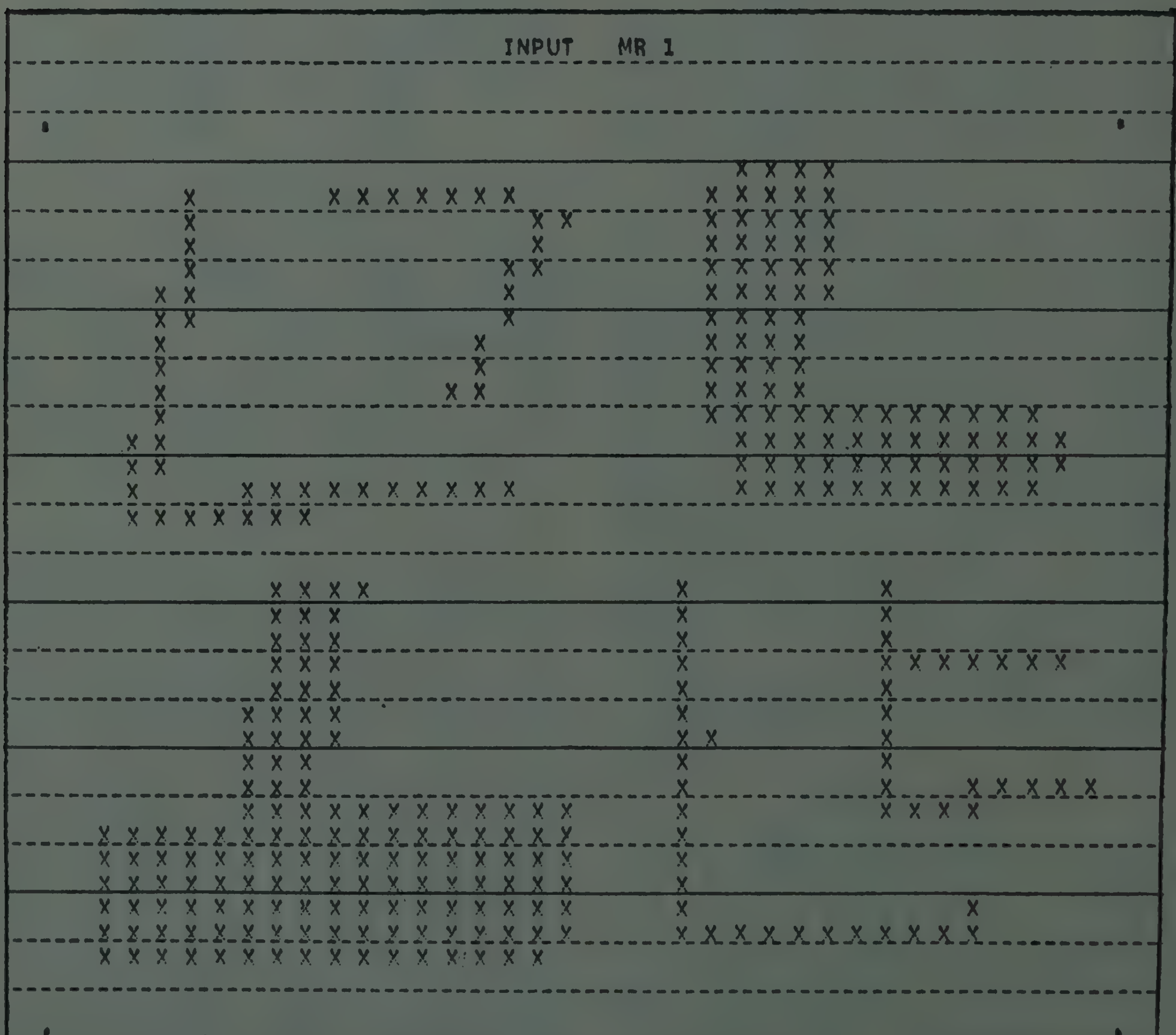


Fig. 11—Input to SPAC L-detection program.

detection program does, the results of one of the experimental 704 runs will be presented now.

The input to the system is a set of figures drawn freehand on a sheet of coordinate paper (Fig. 10). Since a suitable automatic scanning device was not yet available, its action was simulated by a key-punch operator, who was instructed to punch a set of IBM cards to represent the pattern; one column corresponding to each cell of the coordinate paper. A one was punched where the corresponding cell was black and a blank was punched where the corresponding cell was blank. The resulting deck of cards served as the input to the machine. (As can be seen in Fig. 10, a 36×36 array was used.) A print-out of this quantized input is shown in Fig. 11, with x's replacing ones in order to make the form of the figures more conspicuous.

The first step by SPAC was to smooth the input field using a routine carrying out the steps described in the section on smoothing. Details of the smoothing routine will not be presented here.

SPAC then executed the L-detection program, which will be discussed next, and then printed out the result shown in Fig. 12, in which only L-shaped figures (after smoothing) remain.

The program first selects those figures whose edge sequences include LBRTRT, where the first R-edge and the second T-edge can be arbitrarily small, while the other four edges must each be at least four units long. (This permits the detection of "thin" as well as "thick" L's.) From this set, the program eliminates all figures with any edges not in the LBRTRT sequence, leaving figures such as those shown in Fig. 6(b) and Fig. 13(a).

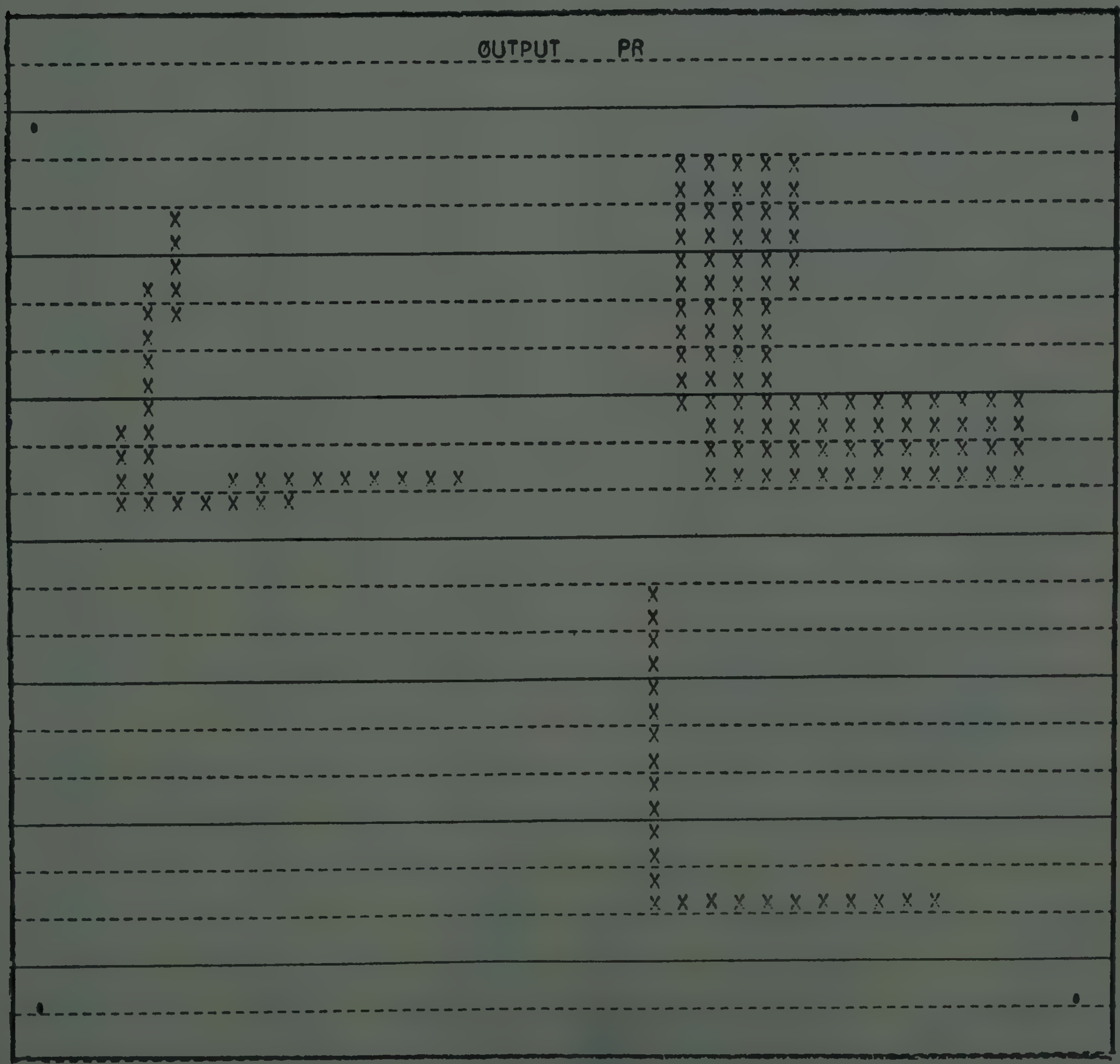


Fig. 12—SPAC output.

The following explanatory notes correspond to the parenthetically numbered points in the program shown in Table I, and the references to lettered edges in these notes pertain to Fig. 13(a).

(1) Left edge points (one-points with zeros to the left) which are in vertical strips of length at least equal to 4 (a-edges).
(2) Adds b-edges (vertical strips of left edge points diagonally below a-edges) to the a-edges found in (1).
(3) Corner points such as the one common to b and c.
(4) MR5 now includes edges a, b, c, and d.
(5) Adds edge e to MR5.
(6) Adds edge f to the edges already in MR5. Note that whereas the left edge of the L, consisting of m, a, and b-edges, must include an a-edge which is at least 4 units long, the portion of the L corresponding to f can be as small as one unit.
(7) Adds g-edge to MR5.
(8) Adds edge h to MR5.
(9) Edge i is added to MR5. The inside corner was "turned" 10 instructions prior to this order by the SHF L and SHF U instructions.
(10)–(13) Edges j, k, and l, are added to MR5.
(14) The PR now contains edge m (which is now also in MR3).
(15) MR2 now contains all edges which are in LBRTR sequences (or subsequences) and *only* such edges.
(16) MR3 now contains the edges found in (15) and the regions enclosed by these edges. In the case of Fig. 13(a), MR3 contains the entire figure. Since only the darkened edges of Fig. 13(b) comprise LBRTRT sequences, MR3 will contain only that part of this figure which is in MR2 (the darkened edges—which enclose no area). MR3 will contain Fig. 13(c) with the hole filled in. Thus, only in the case of true L's such as Fig. 13(a) will MR3 include the whole figure without additions. The remainder of the program consists of eliminating figures which are only partially contained in MR3 [Fig. 13(b)] and figures such as Fig. 13(c) which do not completely cover their counterparts in MR3.
(17) Figures such as 13(c) which have holes.
(18) PR now contains figures such as 12(b) with outer edge sequences including edges other than those in MR2.
(19) Figures found in (17) and (18) are eliminated, leaving only the desired L-shaped figures.

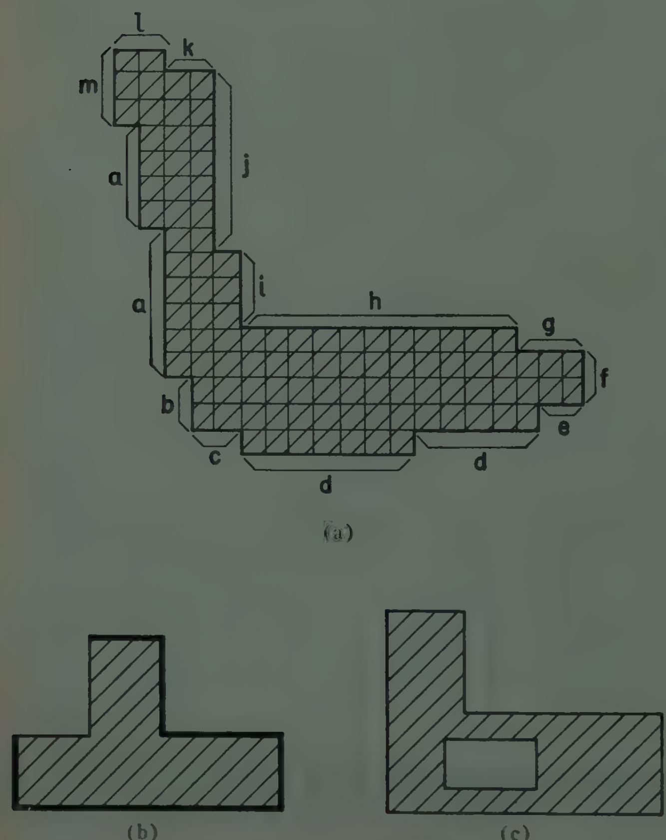


Fig. 13—Illustrating L-detection program.

TABLE I

L-Detection Program

SMOOTH	WRT 3	STR 3
WRT 1	SHF U	WRT 1
SHF R	ADD L, R	SHF D
INV	MPY 4	INV
MPY 1	EXP V, P, N	MPY 1
STR 2	ADD 3	STR 2
LNK	ADM 5 (6)	LNK
MPY U	SHF U	WRT 1
MPY U	ADD L, R	SHF L
MPY U	ADM 3	SHF D
ADD D	WRT 2	INV
ADD D	LNK	MPY 2, 3
ADD D	MPY 3	EXP H
STR 5 (1)	EXP V	STR 3
SHF D	ADM 5	WRT 2
ADD L, R	STR 3	MPY R
MPY 2	WRT 1	MPY R
EXP V	SHF D	MPY R
STR 3	INV	ADD L
ADM 5 (2)	MPY 1	ADD L
WRT 1	STR 2	ADD L
SHF U	LNK	LNK
INV	WRT 1	STR 4
MPY 1	SHF L	WRT 3
STR 2	SHF D	SHF L
LNK	INV	ADD U, D
MPM 3	MPY 2, 3	MPY 4
WRT 1	EXP H	EXP H, P, N
SHF R	ADM 5 (7)	ADD 3
SHF U	SHF L	ADM 5 (12)
INV	ADD U, D	SHF L
MPY 3 (3)	STR 3	ADD U, D
EXP H	WRT 2	ADM 3
ADM 5	MPY L	WRT 2
SHF R	MPY L	LNK
ADD U, D	MPY L	MPY 3
STR 3	ADD R	EXP H
WRT 2	ADD R	ADM 5 (13)
MPY R	ADD R	STR 3
MPY R	LNK	WRT 1
MPY R	MPY 3	SHF R
ADD L	EXP H, P, N	INV
ADD L	ADM 5 (8)	MPY 1
ADD L	SHF L	LNK
LNK	ADD U, D	STR 2
MPY 3	STR 3	WRT 1
EXP HPN	WRT 2	SHF R
ADM 5 (4)	LNK	SHF D
SHF R	MPY 3	INV
ADD U, D	EXP H	MPY 2, 3
STR 3	ADM 5	EXP V
WRT 2	SHF L	STR 3 (14)
LNK	SHF U	ADD 5
MPY 3	STR 3	LNK
EXP H	WRT 1	WRT 3
STR 3	SHF L	EXP H, V, P, N
ADM 5 (5)	INV	STR 2 (15)
WRT 1	MPY 1	INV
SHF L	STR 2	LNK
INV	LNK	MPY 2
MPY 1	MPY 3	ADR
STR 2	EXP V	EXP H, V
LNK	ADM 5 (9)	INV
WRT 1	SHF U	STR 3 (16)
SHF L	ADD L, R	LNK
SHF U	STR 3	WRT 1
INV	WRT 4	INV
MPY 2, 3	LNK	MPY 3
EXP V	MPY 3	EXP H, V, P, N
STR 3	EXP V, P, N	STR 4 (17)
WRT 2	ADM 5 (10)	WRT 1
MPY D	SHF U	LNK
MPY D	ADD L, R	WRT 3
MPY D	STR 3	INV
ADD U	WRT 2	MPY 1 (18)
ADD U	LNK	ADD 4
ADD U	MPY 3	EXP H, V, P, N
LNK	EXP V	INV
STR 4	ADM 5 (11)	MPY 1 (19)

Note that there are no loops in the program, so that each of the 237 SPAC instructions is executed exactly once.

Programs for detecting figures with holes are somewhat more complex. Both inner and outer edge sequences are traced, and, in place of the contents of MR3 described in (16) it is necessary to find the area enclosed between the outer and inner borders. This area is then used in the same manner as the MR3 contents were used in the L-program. However, it is then necessary to eliminate figures with the wrong *number* of holes, or with improperly located holes. This can be done in a variety of ways. One method is to eliminate points between one outer edge of the figure and the hole(s) and then check the edge sequence of the resulting figure, which no longer has any holes.

Figs. 14, 15 and 16 show the results of a test of an A-

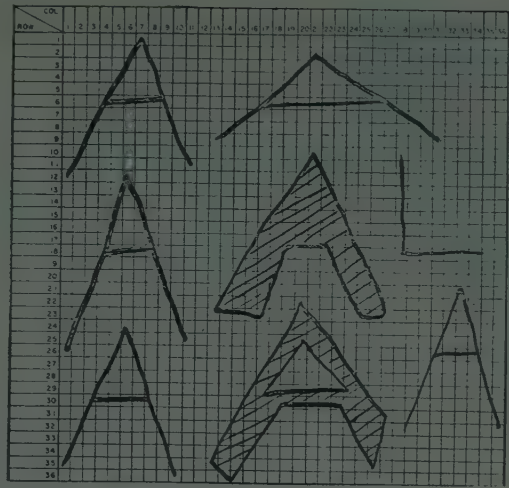


Fig. 14—Original drawing.

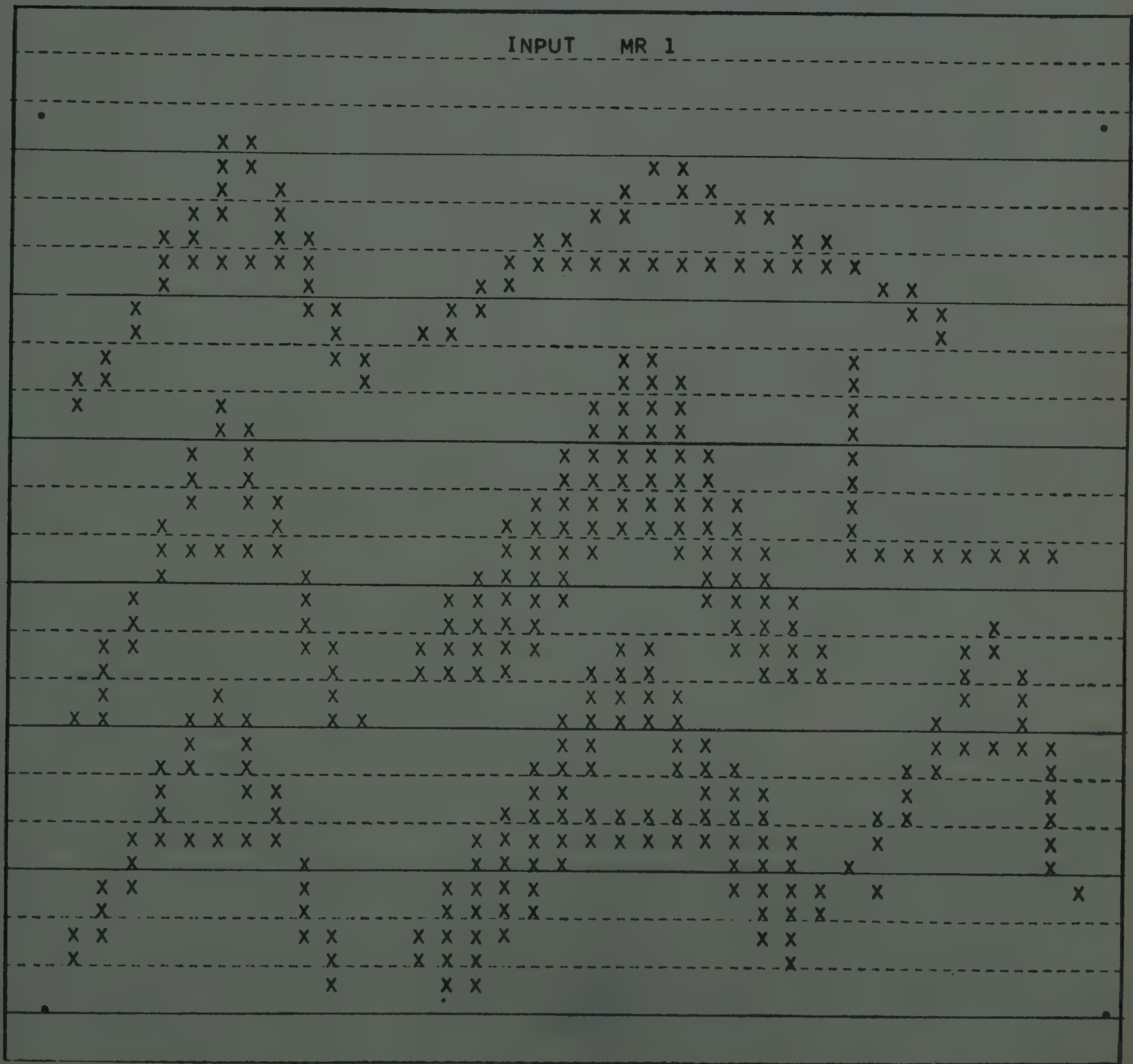


Fig. 15—Input to SPAC L-detection program.

detection program consisting of about 500 orders (including smoothing).

VI. Pattern Recognition

The pattern recognition problem defined earlier in this paper consists of identifying an input figure, given that it belongs to some member of a finite set of categories. For example, the set of categories (henceforth to be referred to as the *alphabet*) might consist of the digits from zero through nine inclusive.

For any alphabet there must exist at least one finite set of characteristics that can be used to distinguish amongst the members. That is, there must exist a set of yes or no questions, such that if these questions are answered with respect to any given figure, then there will be only one member of the alphabet to which this figure can belong. The questions might, for example, concern the presence or absence of such features as holes, straight left edges, or concavities open to the right.

It is not necessary to ask all of the questions in every case. A sequential process can be carried out in which the answer to the first question determines a subset of the alphabet to which the input figure may belong. Depending upon the subset, a second question is asked, the answer to which further narrows the field of possible categories. This process is repeated until a single candidate remains. If the questions can be so chosen that each one halves the number of remaining candidates, then the number of questions necessary to identify any given figure is about $\log_2 n$, where n is the number of members of the alphabet. This is the minimum average

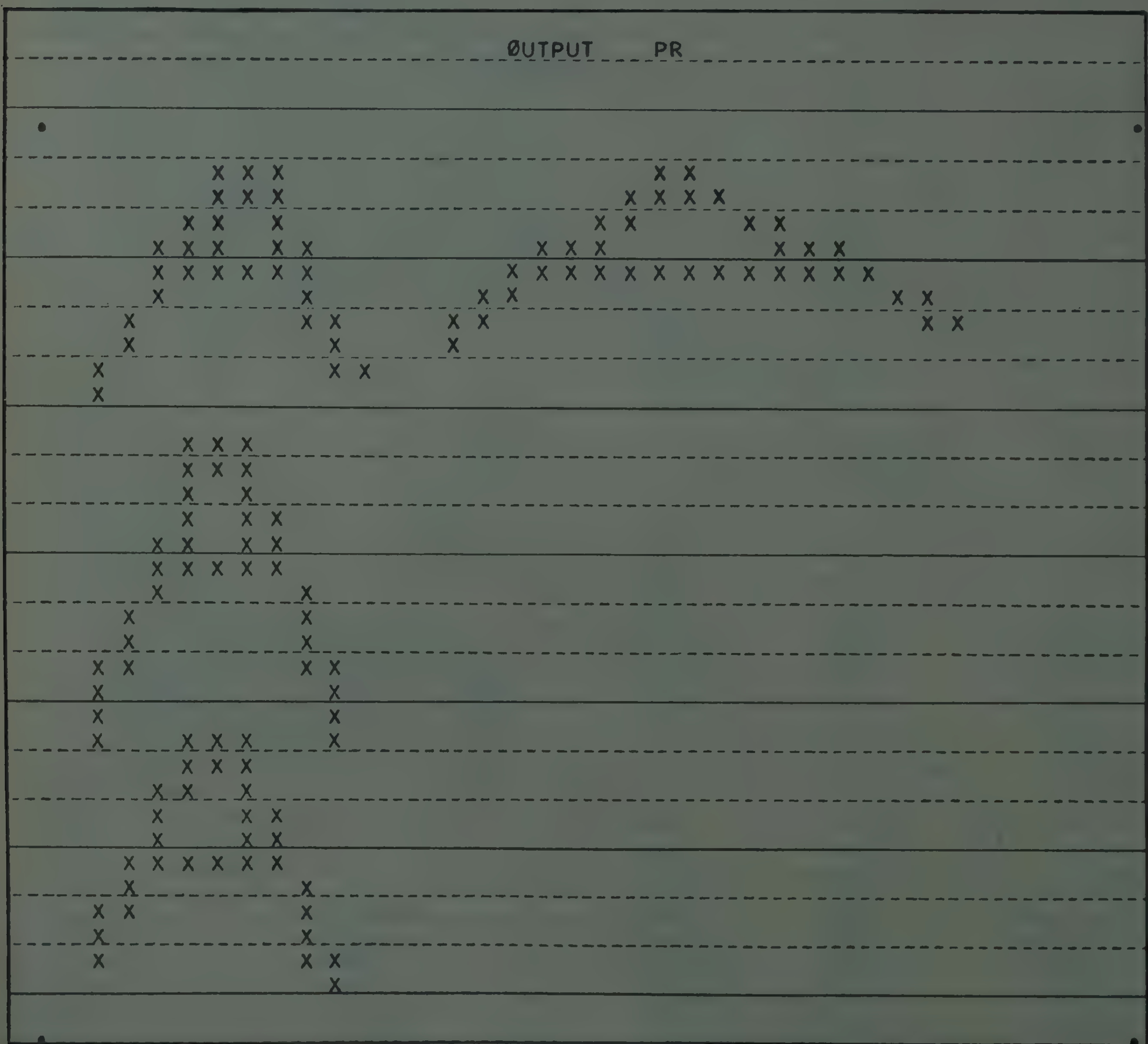


Fig. 16—SPAC output.

number of questions, assuming that the input figure is equally likely to belong to any of the n categories.

A good set of questions should have the following characteristics (insofar as they are mutually compatible):

1) They should be sufficient to distinguish any pair of allowable input patterns that belong to different members of the alphabet.
2) The necessary number of tests that must be performed for each identification should be minimal.
3) The number of orders necessary to perform each test should be minimal.
4) The total number of tests should be minimal.

An ideal property is thus easy to test for, possessed by half of the members of the alphabet (each test must produce a *different* dichotomy), and invariant with respect to all distortions that leave a pattern in the same category within the alphabet. Needless to say, it is not generally possible to attain such an ideal.

A pattern recognition scheme for alphanumeric characters will now be described. It is intended to recognize hand drawn sans-serif capital letters and numerals with very broad limits on the permissible over-all sizes and thicknesses of the input figures. A preliminary smoothing routine as described in Section III serves to cancel out the effects of noise, provided that the noise is not concentrated in any one locale.

The 34 properties described in Table II are used to distinguish among the 34 members of the alphabet (ones do not differ from I's, and zeroes do not differ from O's). Fig. 17 is a flow chart indicating how the tests are used. Starting with property 2 at the top, movement is downward. At each branch point the left branch is taken if the answer to the question referred to by the number is no. The right branch is taken for a yes answer. The following two definitions pertain to Table II:

1) A figure is *vertically concave* if there exist points not on the figure whose vertical projections *both* upward and downward touch the figure. Such points constitute *vertical cavities*. Similar definitions apply to horizontally concave figures, and to $+45°$ and $-45°$ concave figures. Parts (a), (b), (c), and (d) of Fig. 18 illustrate vertical, horizontal, $-45°$ and $+45°$ concave figures respectively, the dotted regions indicating the respective cavities. (This definition will be further qualified later on in the text.)
2) A cavity is *open to the right* if a directed path can be found starting at a point in the cavity, passing through points not on the figure, with no component in a leftward direction, and terminating at a point on the margin of the matrix. Cavities open to the left, or in other specified directions, are similarly defined.

TABLE II

FEATURES USED IN CHARACTER RECOGNITION PROGRAM

1) Horizontal cavity open above, (begj).
2) Vertical cavity open to the right, (aghk).
3) Vertical cavity open to the left, (efghl).
4) Horizontal cavity open below, (fhk).
5) Horizontal cavity, (befghijkl).
6) A hole, (eil).
7) Two vertical cavities lying on a common vertical line with the region between them consisting of points on the figure. For at least part of each cavity, no points on the figure are directly to the left of the cavity. (This latter requirement is a somewhat stricter version of "open to the left"), (e).
8) $+45°$ concave, (defghijkl).
9) A region such that a vertical line segment can be drawn starting on the figure, passing down through a vertical cavity, passing through points on the figure again, then (still moving down) entering another vertical cavity, and finally terminating on the figure, (efghl).
10) Not used.
11) Same as 9), but with a horizontal instead of vertical orientation, (ijk).
12) Vertical cavity, (aefghikl).
13) $-45°$ cavity, (cefghijkl).
14) $-45°$ cavity open in a "left-bottomward" direction, (efghkl).
15) Horizontal cavity not part of a hole, (befghjk).
16) $+45°$ cavity not part of a hole, (defghjkl).
17) Holes whose inverse (complement) is horizontally concave, (l).
18) -45 cavity not part of a hole, (cefghjkl).
19) A vertical left edge with right-angled corners above and below, (acdefjk).
20) Two holes, (i).
21) A horizontal top edge with inside corners on both ends, (ej).
22) Same as 7) except that the cavities are horizontal and they face upward, (j).
23) Same as 7) except that the cavities are horizontal and they face downward, (k).
24) A vertical cavity, the lower end of which is above a bottom edge connected to an upper-left inside corner, (the intersections of a bottom edge and a right edge), (ek).
25) A cavity which is both vertical and horizontal, (efghil).
26) Hole whose inverse is vertically concave, (e).
27) Same as 9) except that the lower vertical cavity is inside a hole, (el).
28) Leftmost point of a vertical cavity open to right higher than the rightmost point of a vertical cavity open to the left, (g).
29) Right vertical edge, (bcdefijk).
30) Not used.
31) Height of the left leg of a U-shaped figure less than half the height of the right leg. (Used only to distinguish a "J" from a "U".)
32) Vertical cavity open to the left. This differs from 3 in that it includes cases where the boundaries of the cavity have nearly vertical slopes. (A fuller explanation of this distinction will be presented in the text.)
33) A right vertical edge with no horizontal cavity on the same level with it. (A Y has this property—but not a V.)
34) Leftmost point of a vertical cavity open to the right lies in the upper two thirds of the figure.
35) Vertical cavity open to right. (See 32.)
36) Horizontal cavity above a vertical cavity separated by part of the figure (efh).

Some of the descriptions in the table are of a qualitative nature, since more detailed statements would be beyond the scope of this paper. Following the description of each feature in the table is a parenthetic note referring to just those parts of Fig. 18 which have that feature. It is hoped that these illustrations will serve to clarify some of the more complex descriptions.

Before discussing some of the interesting features of this problem and our solution let us see how the system would operate in a particular case. Suppose, for example, that the figure to be identified happens to be an

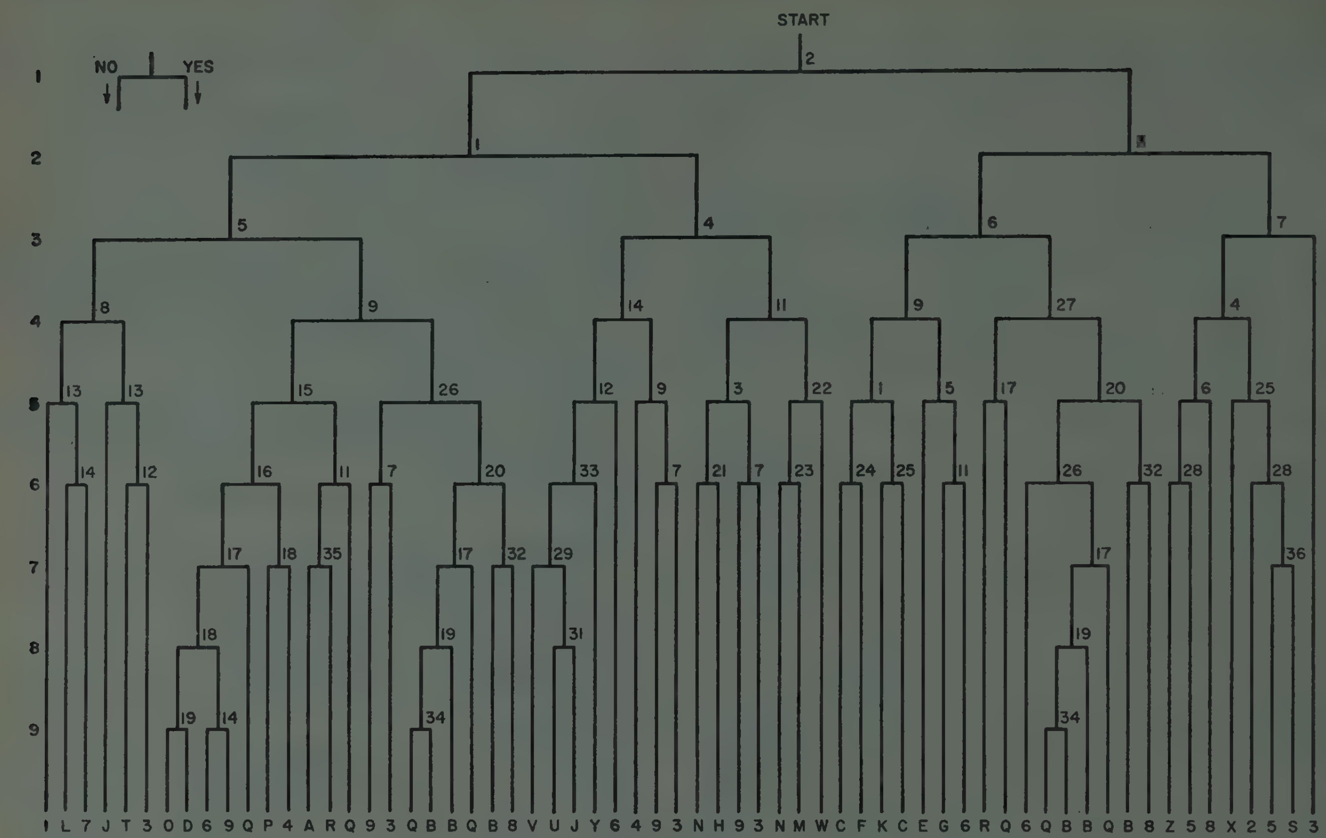


Fig. 17—Flow chart for recognition program.

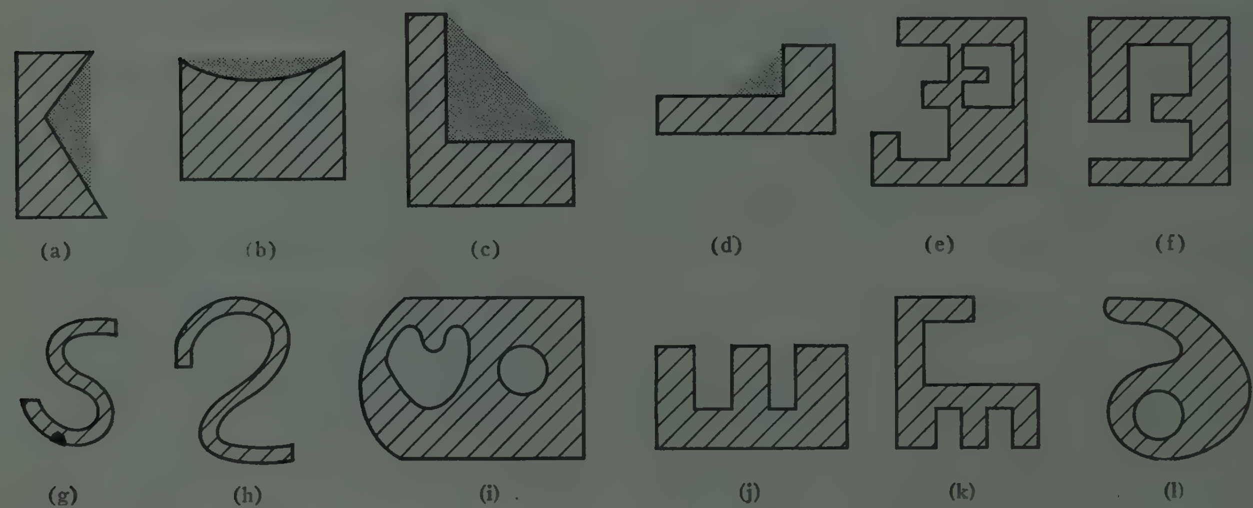
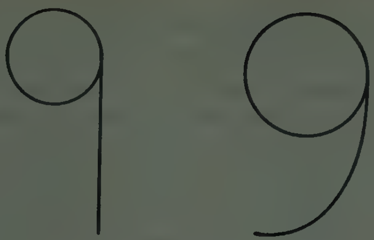


Fig. 18—Illustrations for recognition program features.

"E." Referring to Fig. 18 we see that the first question (2) tests whether there is a concavity open to the right. Since the answer is yes, the right branch is taken, and the next question is 3, "Is there a concavity open to the left?" The answer being no, the left branch is taken and the next question is 6. Questions 9 and 5 follow in succession and a negative answer to the latter leads to the conclusion that the input is an "E."

In order to allow for variations in the forms of certain characters, these characters (such as "3" and "Q") appear at several different terminal points of the flow chart. A "9" for instance may be successfully recognized as drawn in either (a) or (b) of Fig. 19. Thus there are 63 termination points for the 34 characters.

Tests for each characteristic listed in Table II can be carried out by means of subroutines for SPAC. An average of about forty-five orders are required for each test. Thus, roughly three to five hundred orders are re-



(a) (b)

Fig. 19—Illustrating allowable style variations.

quired for each input figure (including one hundred orders to carry out the smoothing process described in Section III). There are about 1600 orders in the entire program, which has been successfully tested by means of the simulated SPAC. A lack of space precludes the presentation of the entire program in this paper, but a representative subroutine will be included.

The subroutine for each test consists of a series of operations carried out on the given figure so that at the end of the routine the field is cleared unless the figure has the property being tested for. Table III consists of a portion of a calling sequence that realizes the first few levels of the flow chart of Fig. 17. The order SBR XXX calls in the subroutine XXX. (For example, to test for property 2 we use the order SBR RO2.) After this subroutine has been executed the next order in the sequence is carried out. The order JMP PRY causes the computer to print a statment to the effect that the input character is a Y.

TABLE III

SBR RO2	TRZ 3
TRZ 1	JMP PR3
SBR RO3	TRA 60 (where a stop order is located)
TRZ 2	1 SBR RO1
SBR RO7	TRZ 4 etc.

An example of a SPAC program for carrying out a typical test is shown in Table IV.

TABLE IV

SPAC SUBROUTINE FOR TEST 9 (TABLE II)

WRT 1	MPY 9	ADD U
ADD L, R	EXP V (3)	STR 7
INV	ADD U	WRT 9
STR 9 (1)	SHF D	LNK
LNK	MPY 1 (4)	MPY 7
WRT 1	STR 7	EXP V
INV	WRT 1	ADD U
STR 8	LNK	SHF D
WRT 1	WRT 7	MPY 1 (6)
SHF D	EXP V	STP
MPY 8 (2)	SHF D	
ADD U	MPY 8 (5)	

The following explanatory notes refer to the numbered instructions in the program.

(1) Zeros, with zeros to the left and right of them.
(2) Points just below bottom edges.
(3) Zeros with upward projections touching ones.
(4) Zeros just below parts of the figure which are below vertical cavities.
(5) Zeros just below parts of the figure which are below vertical cavities.
(6) Ones below two vertical cavities, as required in Table II.

Note that the use of the points obtained in (1) as the possible vertical cavity points prevents a slightly crooked vertical line from being considered as vertically concave.

It will not be possible to discuss in detail all of the problems that lead to the use of the various tests employed in the system described here, but a few samples may serve to give the general flavor.

Consider first the test for a vertical cavity open to the right (test 2). A strict interpretation of this test would mean that a positive result would be obtained in cases typified by a "T" whose vertical member is slanted as shown in Fig. 20. In order to prevent this,

Fig. 20—Illustrating test 2.

the program for test 2 is written so that necessary conditions for a point to be considered as being in a vertical cavity are:

1) It must not be horizontally adjacent to a one-cell;
2) All zero-points in the cavity that are in the same column as the given point must meet condition 1, except possibly those at the top and bottom of the cavity.

These requirements insure that parts of the upper and lower borders of a vertical cavity must both be nearly horizontal. Hence Fig. 18(a) does *not* possess feature 2 as indicated in Table II. In certain cases it may be desirable to detect the presence of vertical cavities whose boundaries do not meet condition 2. Such a cavity is shown in Fig. 21. Test 35 accomplishes this function, in that it does not require the upper and lower cavity boundaries to be nearly horizontal. This characteristic is useful in distinguishing R's from A's.

In order to distinguish Y's from V's, it was found necessary to look for a right vertical edge below the V-shaped notch at the top of the figure. This is property 33 in Table II. A right vertical edge in this case is defined as an edge containing either one vertical strip of

Fig. 21—Illustrating need for test 35.

length at least equal to six or two vertical strips each of length at least equal to three.

The recognition program is preceded by the smoothing routine described earlier in this paper, which eliminates small irregularities. In addition, the various subroutines for detecting features are generally insensitive to fine details, so that the over-all system will operate fairly well in the presence of scattered noise. Fig. 22 is a photograph of a 704 print-out which consists of an input figure and the output statement produced by the recognition program. Such tests have been carried out on about 90 figures. The clumsiness of the procedure for generating input data has precluded more exhaustive experimentation, but the success of the program has been clearly established.

VII. Conclusion

Methods applicable to two classes of problems, pattern recognition and pattern detection, have been developed. Solutions to several specific problems in these areas have been described, namely the recognition of alphanumeric characters, and the detection of L-shaped patterns. The methods and solutions presented here have all been successfully tested by means of a 704 simulation program, and some of the results of these tests have been included.

The matrix size of 36×36 used in these experiments was chosen for its convenience in simulating on the 704, and because it is a reasonably satisfactory size for the complexity of the patterns used in the tests. For applications in which fine details of more complex figures must be studied, a larger matrix will be necessary. A smaller matrix might suffice for simpler applications, although for small matrices the permissible variation in the size of the input image is quite limited, and an important advantage of the techniques described here is lost. On the other hand, as was mentioned in Section II, a matrix that is not too fine will smooth out some of the random irregularities in the input. Of course the principal reason for limiting the matrix size is economic.

Since SPAC does not yet exist as hardware, it is not possible to give actual execution times for the programs included here. However, in view of the simplicity of the logic required for each SPAC order,[1] and the speed of components now in the development stage, it is not unreasonable to assume that, within five years, a speed of one microsecond per order will be attainable. Under this assumption, the character recognition program given here could operate at a rate of about 2500 characters per second (ignoring input time). The time required by the 704 simulation program to execute each SPAC order varies widely as a function of both the data and the instruction. A rough estimate of the time for a "typical" program is 10 msec per order.

In addition to being a fascinating field of study, automatic pattern processing has numerous conceivable applications. Primary interest today is in devices for character recognition, and it is easy to list applications such as transmitting hand written programs and input data to computers without the need for key punch operators, automatic sorting of mail, machine reading of telephone toll tickets written by operators, and machine reading of texts to be automatically translated into other languages.

Pattern detection methods might be useful in biological studies where searches must be made for particular cell structures, bacteria, or viruses among large numbers of microphotographs.[9] Organic chemistry is another field in which important data exist in pictorial form, namely molecular diagrams. Searches for particular kinds of molecular structures among large numbers of records (perhaps in a patent office) may well be facilitated by machines.[10] No doubt other applications will be found as the techniques improve.

VIII. Appendix

The Order Structure of the Spatial Computer (SPAC)

The order structure of SPAC is summarized in Table V, and a brief amplification of some of the descriptions follows. A more complete treatment will be found in a paper mentioned earlier.[1] (Note that some of the abbreviations in this paper will differ slightly from those used in the original description of SPAC.[1])

Suppose, for example, that the order ADD 1, 4 is given. Then, within every module, simultaneously, the contents of MR1 and MR4 will be added to the PR contents (Boolean additions). Note that each module operates on the data in its own memory cells, independently of what is going on in the other modules. The order ADD L, 2 results in the contents of the PR of each module being incremented (again Boolean addition) by the contents of MR2 and the *original* contents of the PR of the neighboring module to the left. Note that ADD L, 2 is not equivalent to ADD 2 followed by ADD L. Other references to neighboring modules used

[9] H. P. Mansberg, "Automatic particle and bacterial colony counter," *Science*, pp. 823–827; October 25, 1957.

[10] L. C. Ray, R. A. Kirsch, "Finding chemical records by digital computers," *Science*, pp. 814–819; October 25, 1957.

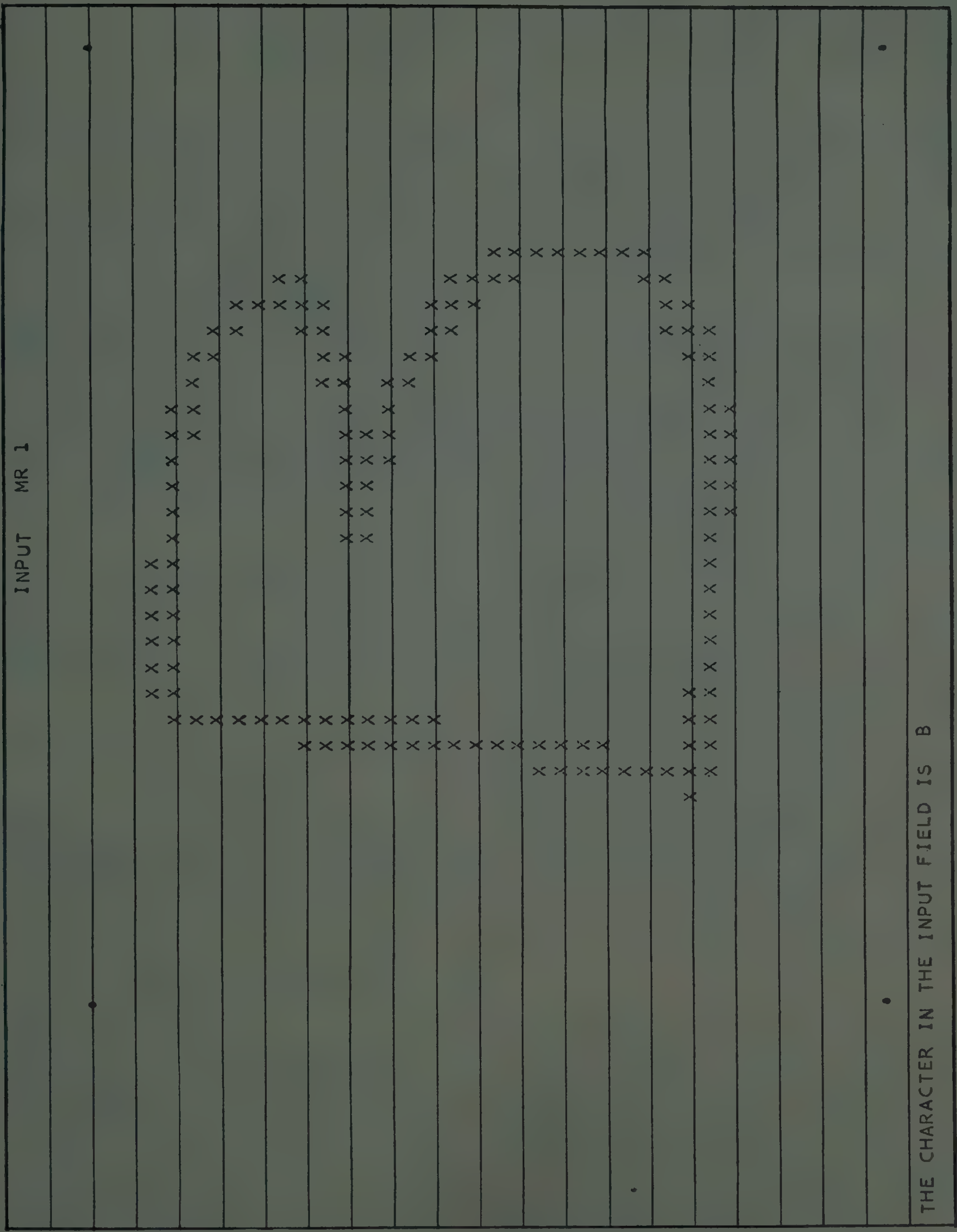


Fig. 22—Example of character recognition.

TABLE V
SPAC ORDER STRUCTURE

Order	Symbol	Interpretation
Write	WRT	Write the contents of the indicated MR into the PR without altering the MR contents.
Store	STR	Store the contents of the PR in each of the specified memory cells without altering the PR contents.
Invert	INV	Change the contents of every PR.
Add in memory	ADM	Add logically to the contents of each specified MR, the contents of the PR, without changing the latter.
Multiply in memory	MPM	Multiply logically the contents of each specified MR by the contents of the PR, leaving the PR contents undisturbed.
Add	ADD	Add logically to the contents of each PR, the contents of the specified MR's and neighboring PR's.
Multiply	MPY	Multiply logically the contents of the PR, the specified MR's and neighboring PR's, placing the result in the PR.
Add Reference	ADR	Add a one to the PR of the module in the lower left corner of the matrix.
Shift	SHF	Write the contents of each PR in the contents of the PR of the module in the specified direction (L, R, U, or D).
Transfer	TRA	Execute the instruction at the indicated address and then continue from there in sequence.
Transfer if zero	TRZ	If every PR contains a zero, then TRA to the indicated address. Otherwise continue with next order.
Link	LNK	Activate link elements between those adjacent pairs of modules in which both PR's contain ones. De-activate all other link elements.
Expand	EXP	Add ones to all PR's connected to PR's with ones through a chain of activated link elements of the orientation(s) specified in this order (H, V, P, N—or any combinations).
Stop	STP	End of program or subroutine.

with the ADD, MPY and SHF orders are R, U, and D referring to right, above (up) and below (down) respectively. Incidentally, it is assumed that a border of modules whose PR contents are permanently zero surrounds the entire matrix.

The link and expand orders require some further clarification. Although they are not shown in Fig. 1, there are one-bit memory elements between every adjacent pair of modules, including diagonal neighbors (so that each module shares eight such elements with its neighbors). These link cells become activated (or de-activated) only when a link order is given, in accordance with the description of that order in Table V. Note that there are four kinds of link cells, depending upon the orientation of the line connecting the two modules that they connect. These are horizontal (H), vertical (V), diagonal with positive slope (P), and diagonal with negative slope (N). An expand order can refer to any combination of these four orientations. When an expand order is given, the activated link cells of the specified orientation(s) establish two-way channels between the modules they connect. A propagation of ones takes place starting from those PR's which contained ones when the EXP order was given, and spreading to all other PR's connected to them via the network of channels.

Although not specifically discussed here, there are means for loading patterns into the module array prior to the executions of a program, and also means for unloading the output. There are also instructions making possible a printed output (required for the recognition program). At this time SPAC exists only in simulated form.

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A Unified Analysis of Range Performance of CW, Pulse, and Pulse Doppler Radar*

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Summary—**This paper presents a unified method for computing detection range of pulse, multi-channel pulse Doppler, and CW radars.**

The method assumes that detection occurs when a set threshold is exceeded and is based on 1) a modification of the conventional radar equation which relates range with the signal-to-noise ratio; 2) a simplified analysis of a single channel consisting of range gate, bandpass filter, square-law detector, and post-detection integrator which leads to an approximate calculation of the probability of detection; 3) a consideration of multi-channel effects.

Although pulse radar has been extensively analyzed, the literature on the performance of CW and pulse Doppler radars is meager. This paper attempts to fill this gap.

The method should prove useful for evaluating changes in a radar or comparing two radars. In order to estimate the radar range of a single radar, experiments to "calibrate" the model are required. A radar whose range is experimentally known can serve as a standard of comparison for predicting the behavior of radars under development.

Examples illustrate the method and suitable graphs are given.

INTRODUCTION

It is by now well established that the problem of predicting the detection range of radars is of a statistical nature. The radar literature contains extensive descriptions and performance analyses of pulse radar systems.[1–12] In comparison, with few exceptions such as Barlow,[13] little has been published regarding the performance analysis of CW and pulse Doppler radars. This paper is an attempt to fill the gap by presenting a unified method for computing the range performance of CW, pulse, and pulse Doppler radars. A common ground is thereby established on which different types of radars and similar radars with different design characteristics can be compared.

In evaluating range performance, it was found useful to follow concepts and methods established for pulse radar. This has the advantage that engineers familiar with the pulse radar method will need a minimum of reorientation. Results are reduced to a simple graphical presentation and to equations employing well-tabulated functions in order to facilitate application even further. No attempt is made either to employ the work on optimum detection techniques[14–18] or to consider fluctuating signals. The latter can be readily treated following the work of Swerling.[12] The detection device assumed is of the type quite likely to be encountered in practice.

The analysis is carried through for a pulse Doppler radar, since the CW and standard pulse radars can be regarded as special cases of the pulse Doppler radar.

The paper begins with a brief description of a pulse Doppler radar. Then some results known to the radar engineer are reiterated. The relationship between radar parameters, target cross section, and a *normalizing radar range* R_0 is re-established with modifications necessary to adapt R_0 to a pulse Doppler radar. These modifications consist of appropriate adjustments in the signal power entering the (square-law) detector and integrator; these adjustments are a consequence of 1) a range gate which eclipses part of the returned pulse, and 2) a filter which passes only the central spectral line. Once the adjustment in signal power is calculated

* Original manuscript received by the IRE, October 10, 1958; revised manuscript received, May 20, 1959.

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12 P. Swerling, "Probability of Detection for Fluctuating Targets," The RAND Corp., Res. Memo RM-1217; March 17, 1954.

13 E. J. Barlow, "Doppler radar," PROC. IRE, vol. 37, pp. 340–355; April, 1949.

14 P. M. Woodward, "Probability and Information Theory," McGraw-Hill Book Co., Inc., New York, N. Y., pp. 31–35; 1953.

15 J. J. Bussgang and D. Middleton, "Optimum sequential detection of signal in noise," IRE TRANS. ON INFORMATION THEORY, vol. IT-1, pp. 5–18; December, 1955.

16 W. W. Peterson, T. G. Birdsall, and W. C. Fox, "The theory of signal detectability," IRE TRANS. ON INFORMATION THEORY, no. PGIT-4, pp. 171–212; September, 1954.

17 D. Middleton and D. Van Meter, "Detection and extraction of signals in noise from the point of view of statistical decision theory," *J. Soc. Ind. and Appl. Math.*, vol. 3, pt. 1, pp. 192–253; December, 1955; vol. 4, pt. 2, pp. 86–119; June, 1956.

18 R. F. Drenick, S. Gartenhaus, and P. Nesbeda, "Detection of coherent and noncoherent pulsed signals," PROC. IRE, vol. 43, p. 370; March, 1955.

for each type of radar, the treatment of the problem is identical for the several types of radar. The statistical problem of analyzing a single channel consisting of a square-law detector, a post-detection integrator, and a threshold is handled by approximating the detector output with a staircase wave made up of independent segments. The technique used here reduces the analysis of the continuous process to the treatment of a sum of discrete variables. The distribution of the sum which represents the output of the post-detection integrator is assumed to have the form of a Gamma distribution having a mean and a variance which can be calculated from the mean and the variance of the input distribution function. This assumption is suggested by the fact that 1) the output of the integrator is a non-negative quantity, 2) for the case of noise alone the assumed distribution is exact when the predetection filter is ideal and a close approximation when the predetection filter is narrowband RLC,[19,20] and 3) a check of the present method against values computed using Incomplete Toronto Functions[1,2] shows excellent agreement. This approach of assuming an appropriate distribution of integrator voltage at the outset permits the analysis not only of a simple integrator which sums up the last N pulses but also of a weighted integrator such as an RC low-pass filter without recourse to the characteristic function employed by Emerson[21] and Kac and Siegert.[22] In particular, the present method simplifies actual computations.[23]

Probabilities of detection and false alarm are obtained by integrating the distribution discussed above. The integrals yield incomplete Gamma functions which are tabulated only for limited values of parameters. This difficulty is, however, overcome by applying the approximation of Wilson and Hilferty to the Incomplete Gamma Function[24] which involves only the well-tabulated Error Function.[25] A check against values tabulated by Pachares[26] of high percentage points of the Gamma distribution reveals agreement within the accuracy of the graphs.

Finally, results are extended to the multiple-channel case. Special graphs of probability of detection vs normalized range are given for an unweighted integrator as an aid to practical computation and their use is illustrated by an example. The graphs are of different form from those of Marcum[1,2] since they eliminate threshold as an explicit parameter and use only radar design quantities, such as false alarm rate, number of filter channels, filter bandwidth, and time on target as entries. These graphs can be used for both the CW and pulse radar analysis.

While different workers in the field have been using various methods for radar range evaluation, the outline of an over-all procedure, the construction of helpful graphs, and the emphasis on simplicity of presentation are in themselves an important contribution towards unifying the methods of realistically evaluating the performance of different radars. An abbreviated and partial version of this work was presented by the authors at the National Conference on Aeronautical Electronics held in Dayton, Ohio, on May 12–14, 1958.

Brief Description of a Simple Pulse Doppler Radar

A block diagram of a simple Doppler radar adequate for the purpose of this analysis is given in Fig. 1(a). The energy transmitted by the radar consists of a coherent train of pulses at carrier frequency f_0. The envelope of these pulses is shown in Fig. 2(a). Pulse duration τ and pulse repetition T are assumed constant. Echoes from a target compose the train of a duration corresponding to target illumination time T_i, as shown in Fig. 2(b). The carrier frequency of the returning radiation is shifted from the transmitted frequency f_0 by an amount f_D called the "Doppler frequency" which is twice the ratio of the relative velocity (of the transmitter and the reflector) to the wavelength of transmitted radiation. The returned pulses, after amplification, are passed through a range gate.

The detection device is illustrated in Fig. 3. It consists of a certain number of narrow band-pass filters covering the Doppler region of interest. A narrow-band filter extracts only one spectral line from the pulse spectrum, thus converting the pulse train to a continuous wave. Each (predetection) band-pass filter is followed by an envelope detector and by a post-detection integrator (PDI). Normally, a square-law envelope detector followed by a linear integrator is the most convenient case to handle. The output of the integrator is applied to a threshold device. An alarm results if the integrated voltage exceeds the threshold. More than one range gate could be used, each followed by a detection device. If the range gate is omitted, and CW transmission used, Fig. 1(a) represents a model of a CW radar.

A common modification of the system in Fig. 1(a) is shown in Fig. 1(b). After (or before) range gating, the returned signal is applied to a coherent detector. This detector is, in essence, a mixer which uses for its refer-

[19] S. O. Rice, "Mathematical Analysis of Random Noise," Bell Telephone Systems, Monograph B-1589; 1944–1945.

[20] D. Slepian, "Fluctuations of random noise power," *Bell Sys. Tech. J.*, vol. 37, pp. 163–184; January, 1958.

[21] R. C. Emerson, "First probability densities for receivers with square-law detectors," *J. Appl. Phys.*, vol. 24, pp. 1168–1176; September, 1953.

[22] M. Kac and A. J. F. Siegert, "On the theory of noise in radio receivers with square-law detectors," *J. Appl. Phys.*, vol. 18, pp. 383–397; April, 1947.

[23] Since the first two moments are sufficient to represent the assumed distribution, the method used is straightforward for a large class of filters. Emerson, *op. cit.*, on the other hand, first derives the characteristic function of the integrator output, then computes the cumulants or semi-invariants from it and uses these cumulants to get an asymptotic expression for the output distribution. The characteristic function method is involved because the characteristic values of a difficult integral equation have to be found.

[24] M. G. Kendall, "Advanced Theory of Statistics," Hafner Publ. Co., New York, N. Y., vol. 1; 1952.

[25] This approximation has been suggested by R. Terzian, RCA, West Coast Electronic Products Div., Los Angeles, California.

[26] J. Pachares, "A table of bias levels useful in radar detection problems," IRE Trans. on Information Theory, vol. IT-4, pp. 38–45; March, 1958.

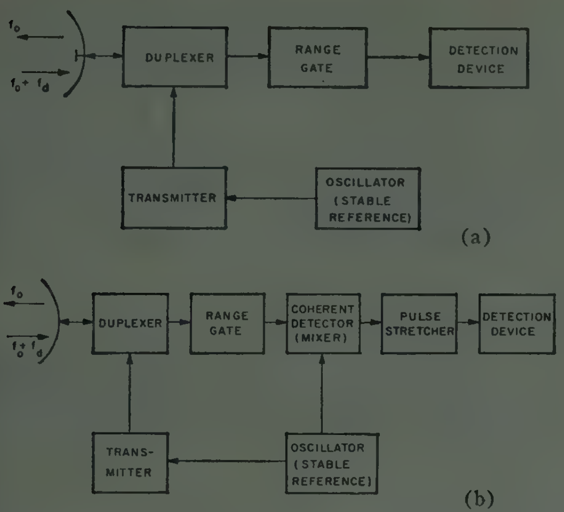

Fig. 1—(a) Block diagram of a simple pulse Doppler radar. (b) Block diagram of a modification of a pulse Doppler radar.

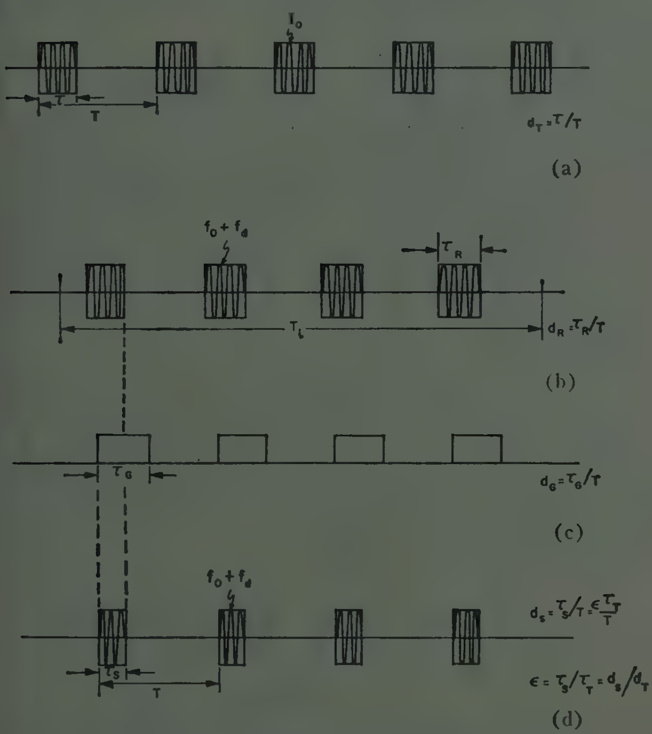

Fig. 2—(a) Transmitted pulses. (b) Returned pulses. (c) Receiver gate. (d) Signal pulses available for detection after gating.

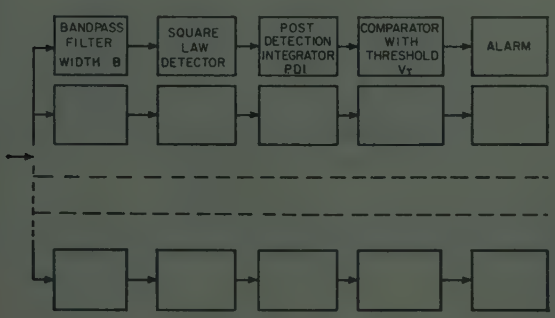

Fig. 3—Block diagram of the detection device.

ence a signal from the oscillator employed to generate pulses. The output of the coherent detector is a series of pulses amplitude-modulated by the Doppler frequency. In order to produce an amplifying effect, these pulses are stretched by a "boxcar" circuit. The stretched pulse train is applied to the detection device of Fig. 3, properly positioned in frequency.

In practice, heterodyning operations may increase the complexity of the system but this in no way detracts from the generality of the model.

Signal-to-Noise Ratio and the Normalizing Range R_0

The fundamental quantity in radar detection theory is the ratio of signal energy available for detection in a particular detection scheme to the competing noise energy.[14] When signal and noise are present over the same period of time, which is the case here, their energy ratio is equivalent to the *average power ratio*. Since, in practice, the physical quantity measured is power, an analysis in terms of average power rather than energy has been preferred. The average is taken over the period of activity of the signal source.

As the first step in the analysis, the signal-to-noise average power ratio at the output of a single narrow band-pass filter and entering the (square-law) detector and integrator is calculated.

Because of receiver gating and filtering, not all the transmitter power is ultimately used for detection. Let $\overline{P}_E$ be that portion of average transmitted power which is actually used in the detection process and termed by us the *effective signal power*. The concept of effective signal power, $\overline{P}_E$, is introduced in order to apply effects of receiver processing directly to transmitted quantities.

Similarly, we define the effective noise power, N_E, as that amount of noise generated at the receiver input which competes with signal at the input of the detector. Then the average signal-to-noise power ratio, X, at the input to the detector is given by

$$X = \frac{\overline{P}_E G^2 \lambda^2 \sigma_T L}{(4\pi)^3 N_E R^4} \tag{1}$$

where

$\overline{P}_E$ = effective signal power (that portion of the transmitted average power which is used in detection).
G = one-way antenna gain.
λ = wavelength of transmission.
σ_T = target radar cross section.
L = product of system losses in two directions, such as losses due to plumbing, radome, propagation, and beam shape.
N_E = effective noise power (that portion of receiver input noise which interferes with detection).

In (1) $\overline{P}_E$ and N_E take into account modifications in both signal and noise powers due to gating and filtering. For example, for the system of Fig. 1(a), the range gate

admits, in general, only a fraction ϵ of each transmitted pulse, where ϵ is the ratio of pulse width after gating to the transmitted pulse width; ϵ can be termed the *eclipsing factor* (see Fig. 2). If the transmitter duty ratio is d_T and the duty ratio of signal pulses after gating is d_s, $\epsilon = d_s/d_T$. Following the range gate a filter extracts only that fraction of signal energy which is contained in the principal spectral line. A simple Fourier analysis shows that this fraction is only d_s of the total. Since the average power transmitted is the product of peak transmitted power $\widehat{P}_T$ and the duty ratio d_T, one concludes that for the example of Fig. 1, the *effective signal power* is

$$\overline{P}_E = (\hat{P}_T d_T) \cdot \epsilon \cdot d_s = \hat{P}_T d_s^2 = \hat{P}_T \epsilon^2 d_T^2 \quad (\epsilon \leq 1). \quad (2)$$

By the same token, a Fourier analysis of gated noise shows that noise power per cps after gating is reduced approximately by the receiver duty ratio, d_G, from the standard $kT(NF)$.

Hence, for the example of Fig. 1, the effective noise power at the output of narrow-band filter is

$$N_E = kT(NF)Bd_G \quad (3)$$

where

kT = product of Boltzmann's constant and the absolute temperature.
(NF) = over-all average receiver noise figure.
B = noise bandwidth of the band pass filter (Fig. 3).[27]
d_G = gating duty factor [(Fig. 2(c)].

Substituting into (1), one finds that, for a single channel of the system of Fig. 1, the signal-to-noise ratio at the detector input is

$$X = \frac{\hat{P}_T d_T^2 \epsilon^2 G^2 \lambda^2 \sigma_T L}{(4\pi)^3 kT(NF) B d_G R^4} \cdot \quad (4)$$

In practice d_G and d_T may be equal.

For the model of pulse Doppler radar involving pulse stretching prior to filtering [see Fig. 1(b)], both the effective signal power and the effective noise power are modified by the envelope of the spectrum of stretched pulses.[28] It follows that the signal-to-noise ratio given by (4) is still a good approximation if each filter extracts only a narrow band of Doppler frequency and rejects repetition rate sidebands.

Define a *normalizing range* R_0 as the range for which $X=1$. Letting $\hat{P}_T d_T = \overline{P}_T$ (transmitted average power), we have from (4)

$$R_0 = \left[\frac{\overline{P}_T d_T \epsilon^2 G^2 \lambda^2 \sigma_T L}{(4\pi)^3 kT(NF) B d_G}\right]^{1/4} \cdot \quad (5)$$

All the radar parameters are locked in R_0. R_0 is just a normalizing quantity for a single channel and should not be treated as the actual detection range. The operation of the detector itself and of multiple channels is not yet taken into account in R_0.

It can be shown with simple arguments that (5) can be applied to various types of radar.

Case 1—Pulse Doppler Radar

This case is discussed above in transition from (1) to (4). Eq. (5) applies to both the model of Fig. 1 and the modified model of Fig. 1(a).

Case 2—CW Radar

In a CW radar, the transmitter and the receiver are on continuously; thus, in (5), d_T, d_G, and ϵ are equal to unity.

Case 3—Pulse Radar

The noise bandwidth is now the IF bandwidth B_{IF} which is wide enough to pass all the significant components of the pulse spectrum and not just the principal spectral line; hence, the factor $d_T\epsilon = d_s$ in (5) has to be omitted. If effects of eclipsing can be neglected and hence ϵ set equal to unity and if $d_T/d_G = 1$, (5) becomes

$$R_0 = \left[\frac{\bar{P}_T G^2 \lambda^2 \sigma_T L}{(4\pi)^3 kT(NF) B_{IF}}\right]^{1/4} \cdot \quad (6)$$

In (6) B_{IF} is assumed to match the pulse width. This is the standard radar range equation (see Ridenouer[29]).

Case 4—Delay-Line MTI Radar

A delay-line MTI operating at a repetition rate f_R acts as a linear filter modifying the spectrum of the signal with Doppler frequency f_D and the spectrum of noise by the same factor $\sin(\pi f_D/f_R)$. Therefore, if the output of the delay line canceller is passed through a narrow-band filter, (4) still represents approximately the average signal-to-noise power ratio at the output of the narrow-band filter. Hence the normalizing range R_0 is still given by (5). This is identical with the argument above on the effect of pulse stretching. In the presence of clutter signal-to-clutter ratio is more significant than signal-to-noise ratio.

[27] The "noise bandwidth" of a narrow-band filter is defined by $B = \int_0^\infty |y(f)|^2 df / |y(f_c)|^2$ where $y(f)$ is the transfer characteristic of the filter and f_c its center frequency. Other definitions of bandwidth in current use can be related to the "noise bandwidth" using the $y(f)$ of each given filter. For an ideal filter $|y(f)| = |y(f_c)|$ for $f_a < f < f_b$, and 0 elsewhere. Hence for an ideal filter $B = f_b - f_a$.

[28] Lawson and Uhlenbeck, *op. cit.*, see sections 3.4 and 10.4.

[29] L. N. Ridenour, "Radar System Engineering," M.I.T. Rad. Lab. Ser., McGraw-Hill Book Co., Inc., New York, N. Y., vol. 1, chaps. 5, 16, 1947.

In summary, although in the standard radar range (6) only the peak signal power appears, the broader concept of *energy ratio* expressed by (1) is more fundamental and includes the radar cases listed above as special examples.

In the discussion that follows, it is possible to relate immediately the signal-to-noise average power ratio (or energy ratio) X to the normalized, dimensionless range quantity R/R_0, since from (4) and (5)

$$R/R_0 = X^{-1/4}. \tag{7}$$

The analysis of a single-channel square-law detector and integrator which follows is carried out in terms of the quantity X. A system of M adjacent ideal filters, each of width B, has a noise power MN_E. Hence the over-all signal-to-noise ratio X_0 at the input of the filter bank is

$$X_0 = X/M, \tag{7a}$$

and

$$R = R_0/(MX_0)^{1/4}. \tag{7b}$$

Representation of Detector Output

Since detection is said to occur when a threshold is exceeded, the problem becomes ultimately one of determining the probability of such an event. This involves tracing the probability distribution of amplitudes through various operations. First we consider the voltage $g(t)$ at the output of the narrow-band filter and input to the square-law detector. This voltage consists of a sine wave plus noise. Let $f(t)$ be the envelope of $g(t)$.

The associated signal-to-noise ratio X was discussed above. The voltage, $v(t)$, at the output of a square-law detector is, by definition, $v(t) = \frac{1}{2}f^2(t)$, where the arbitrary factor $\frac{1}{2}$ is of no consequence and is selected to simplify (8) and (9) which follow. Let v be the normalized variable representing the output of this square-law detector in units of mean square noise. The probability density function of the envelope is for noise alone,[19]

$$P_N(v)dv = \begin{cases} e^{-v}dv & v > 0 \\ 0 & v < 0 \end{cases} \tag{8}$$

and for signal-plus-noise

$$p_{S+N}(v)dv = \begin{cases} e^{-v-X}\, I_0(2\sqrt{vX})dv & v > 0 \\ 0 & v < 0 \end{cases}. \tag{9}$$

We now introduce a simplified mathematical model of the voltage at the output of a square law envelope detector. The continuous voltage is approximated by a function which is constant for intervals of duration $1/B$ and statistically independent in different intervals. The times at which the function changes its value are assumed unknown. An example of such a function is shown in Fig. 4. The height of v_i of each segment follows the same probability density function as (8) and (9). For the ideal predetection filter, Maximon and Ruina[30] have justified this model by showing excellent agreement between the results of integrating the continuous noise process due to Rice[19] and the results of integrating the model waveform, both for noise alone and signal-plus-noise.

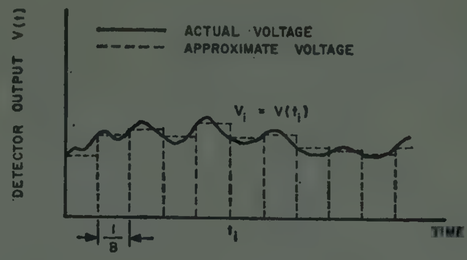

Fig. 4—Approximation of the detector output.

For predetection filters with RLC and Gaussian transfer characteristics, the agreement is still excellent for a large signal-to-noise ratio and moderately good for small signal-to-noise ratio provided enough segments are considered.[30]

With the representation of the detector output assumed above, the normalized input voltage of the PDI is given by

$$v(t) = \sum_{n=-\infty}^{N-1} v_n a\left(t - \frac{n}{B}\right) \tag{10}$$

where N/B is the expected duration of the signal, where

$$a(t) = \begin{cases} 1 & 0 < t < 1/B \\ 0 & \text{elsewhere,} \end{cases}$$

and where the v_n are independent and follow the density laws of (8) and (9). The initial point has been arbitrarily selected and is of no importance.

If a detector which is not quadratic were to be considered, the model (10) of output voltage could still be used, but a different density function would have to replace (9). For the pulse radar, N is the actual number of pulses.

Representation of PDI Filter Output

The problem of determining exactly the probability density function of the voltage at the output of a postdetection integrator has been treated by Kac and Siegert.[22] Their method is not suitable for engineering computations. A simpler approximate approach is adopted here. We assume immediately a reasonable representation of the density function of voltage, V, at the output of PDI. The form which suggests itself whenever the

[30] L. C. Maximon and J. P. Ruina, "Some statistical properties of signal plus narrow band noise integrated over a finite time interval," *J. Appl. Phys.*, vol. 27, pp. 1442–1448; December, 1956.

required probability density $P(V)$ is zero for all negative values of V is given by

$$P(V)dV = \frac{\lambda_1}{\lambda_2}\frac{1}{\Gamma\left(\frac{\lambda_1^2}{\lambda_2}\right)}\left(\frac{\lambda_1}{\lambda_2}V\right)^{\lambda_1^2/\lambda_2-1} e^{-(\lambda_1/\lambda_2)V}dV \quad (11)$$

where λ_1 and λ_2 are, respectively, the mean and the variance of V.[31] The probability density defined by (11) is exactly the distribution of V if noise alone is present and the integrator is an unweighted adder. If signal is also present, the quality of the approximation depends on the signal strength. Combined with the voltage model of (10), this method permits an approximate treatment of integrators with complicated weighting functions and even infinite samples with the use of just the average and the variance of detector output voltage.[32] The procedure connecting V and v is outlined below.

Let $h(t)$ be the impulse response of the PDI filter. Then the output of the filter is given by

$$V(t) = \int_0^t h(\tau)\sum_n v_n a\left(t - \tau - \frac{n}{B}\right)d\tau \quad (12)$$

or

$$V(t) = \sum_{n=-\infty}^{n=N-1} v_n A_n(t) \quad (13)$$

in which

$$A_n(t) = \int_0^{1/B} h\left(t - \tau - \frac{n}{B}\right)d\tau. \quad (14)$$

Eq. (13) indicates that the output of the PDI filter can be regarded as a weighted sum of independent samples of the detector output v. This means that if the mean $\bar{v}$ and variance σ_v^2 of the voltage at the detector output are known, then the mean λ_1 and the variance λ_2 of V at the output of PDI are

$$\overline{V} = \lambda_1 = \bar{v}_0 \sum_{n=-\infty}^{-1} A_n + \bar{v}_s \sum_{n=0}^{N-1} A_n \quad (15)$$

$$\sigma_V^2 = \lambda_2 = \sigma_{v_0}^2 \sum_{n=-\infty}^{-1} A_n^2 + \sigma_{v_s}^2 \sum_{n=0}^{N-1} A_n^2 \quad (16)$$

where subscripts 0 and s denote noise alone ($X=0$) and signal-plus-noise ($X\neq 0$). For each specific integrator only the evaluation of (15) and (16) and substitution of λ_1 and λ_2 thus obtained in (11) is required. Two examples of integrators follow.

[31] Eq. (11) represents a density function known in statistics as Pearson Type III. (See Kendall, *op. cit.*) It can also be regarded as the first term of the expansion in a series of generalized Laguerre functions

$$P(V) = \sum_{n=0}^{\infty} c_n e^{-V} V^d L_n^d(V).$$

[32] P. Nesbeda, "The Metrechon as a Practical Signal Integrator," RCA internal memo.; May, 1954.

Examples of Specific PDI Integrators

Example 1—Unweighted Integrator Matched to Signal Duration

The simplest case is that of integration with uniform weight over a finite time T_i corresponding to signal duration (target illumination time). With the application of the model input, the integrator becomes an unweighted adder of $N=BT_i$ independent samples containing signal-plus-noise. From (9), which describes statistics of the PDI input, we have

$$\bar{v} = 1 + X \quad \text{and} \quad \sigma_v^2 = 1 + 2X. \quad (17)$$

Hence (15) and (16) for this integrator are

$$\overline{V} = \lambda_1 = BT_i(1 + X) \quad (18)$$

and

$$\sigma_V^2 = \lambda_2 = BT_i(1 + 2X). \quad (19)$$

On substitution into (11) the probability density of PDI output follows.

Example 2—RC Filter

The weighting function of an RC filter is

$$h(t) = \begin{cases} \frac{1}{T}e^{-t/T} & \text{for } t > 0 \\ 0 & \text{for } t < 0 \end{cases} \quad (20)$$

where $T=RC$ is the time constant of the network. This filter performs both integration and averaging. We assume that noise alone is integrated from $t=-\infty$ to the time $t=0$ at which signal appears, and signal-plus-noise is integrated from $t=0$ to $t=T_i$, where T_i is the duration of the signal.

Applying again (15) and (16), we find that the PDI output at time $t=T_i$ is characterized by

$$\lambda_1 = \overline{V} = 1 + X(1 - e^{-T_i/T}) \quad (21)$$

and

$$\lambda_2 = \sigma_V^2 = \frac{(1 - e^{-1/BT})}{(1 + e^{-1/BT})}\left[1 + 2X(1 - e^{-2T_i/T})\right]. \quad (22)$$

While the technique for treating an RC post-detection integration filter is only approximate, results are in a form eminently suitable for numerical evaluations.

Definition of Signal Detection, False Alarm and Bias Level

We give first a definition of detection. A signal is said to be detected whenever the channel output exceeds a certain predetermined value V_T, hereafter called the *bias level* or *threshold*.

The probability of detection, P_D, of signal-plus-noise in a single channel is then by definition

$$P_D = \int_{V_T}^{\infty} P_S(V)dV \quad (23)$$

where $P_S(V)dV$ denotes the probability density function of the voltage at the output of PDI when signal is present [*cf.* $P(V)dV$ in (11) with a suitable λ_1 and λ_2].

In the absence of any signal this bias level will, on occasion, be exceeded by noise alone, thus causing a *false alarm*. The higher the bias level is set, the less frequently this happens.

Let P_{FA}' denote the probability of false alarm in a single channel; then by definition

$$P_{FA}' = \int_{V_T}^{\infty} P_0(V)dV \tag{24}$$

where $P_0(V)dV$ denotes the probability density of the output of the PDI for noise alone, $X=0$; [*cf.* $P(V)dV$ in (11)].

In a multi-channel system, *e.g.*, the one described in Fig. 3, the false alarm is said to have occurred if the bias level is exceeded by noise alone in at least one of the channels. If the receiver consists of M parallel channels, the probability of false alarm of the system is then

$$P_{FA} = 1 - (1 - P_{FA}')^M \tag{25}$$

with the assumption that the output of a channel be independent of that of other channels, *i.e.*, that any channel is equally likely to produce a false alarm.[33] For a small probability of false alarms (25) becomes

$$P_{FA} \doteq MP_{FA}' \text{ for } P_{FA}' \ll 1. \tag{26}$$

In practice, the average time T_{FA} between alarms, rather than P_{FA}, is specified. Let T_{FA} denote the system false alarm time and T_{FA}' denote the single channel false alarm time. Then we have for a system consisting of M independent channels

$$T_{FA} = T_{FA}'/M. \tag{27}$$

To relate the system false alarm time with the bias level one needs to express the single channel probability of false alarm, P_{FA}', as a function of the false alarm time. This can be expressed by[34]

$$T_{FA}' = T_i/P_{FA} \tag{28}$$

where T_i is the integration time which ordinarily corresponds to the signal duration. Hence

$$P_{FA}' = T_i/(MT_{FA}). \tag{29}$$

The bias level can be therefore determined by eliminating P_{FA}' between (24) and (29).

Evaluation of P_D and V_T

The evaluation of the probability of detection follows by substituting (11) for $P_S(V)$ in (23).

If one defines, after Pearson,[35] the integral

$$I(u, p) = \int_0^{u\sqrt{p+1}} \frac{e^{-x}x^p dx}{p!} \tag{30}$$

as the Incomplete Gamma Function, the probability of detection is given by

$$P_D = 1 - I\left[\frac{V_T}{\sqrt{\lambda_2}}, \frac{\lambda_1^2}{\lambda_2} - 1\right]. \tag{31}$$

The function I is tabulated only for a limited range of its argument

$$\lambda_1^2/\lambda_2 - 1 < 50.^{35}$$

Using the method developed by Wilson and Hilferty and described in Kendall,[36] we can approximate the Incomplete Gamma Function with the aid of Error Integrals. Wilson and Hilferty noted that if the distribution of V is of the form given by (11), for large values of λ_1^2/λ_2 the distribution of the variable $(V/\lambda_1)^{1/3}$ approaches a normal distribution with the mean $m=1-\lambda_2/(9\lambda_1^2)$ and a standard deviation, $\sigma=(\lambda_2/9\lambda_1^2)^{1/2}$. Hence, we obtain

$$P_D \approx \frac{1}{\sqrt{2\pi}} \int_s^{\infty} \exp\left(-\tfrac{1}{2}u^2\right)du \tag{32}$$

in which

$$s = \left[\left(\frac{V_T}{\lambda_1}\right)^{1/3} - \left(1 - \frac{\lambda_2}{9\lambda_1^2}\right)\right] + \left(\frac{\lambda_2}{9\lambda_1^2}\right)^{1/2} \tag{33}$$

and λ_1 and λ_2 are the mean and variance of PDI output in the presence of signal, *e.g.*, (18) and (19) or (21) and (22). This approximation is considerably better than the usual one that V itself tends to a normal distribution.

Since P_{FA}' is given by the same expression as P_D, *cf.* (23) and (24), except that λ_1 and λ_2 are evaluated for $X=0$ (no signal), it follows that (32) and (33) can be used to derive the threshold V_T for a given false alarm probability P_{FA}' or false alarm time, T_{FA}.

The threshold value can therefore be eliminated from the expressions for P_D (32) and (33) once P_{FA}' or T_{FA}' is specified. This has been done for certain illustrative values. By applying successively (6), (32) and (33), graphs of the probability of detection P_D vs the normalized range R/R_0 have been constructed.

The Use of Graphs

A set of graphs is included in this paper to assist the designer in the task of determining the detection range in specific instances. These graphs have been constructed in order that computations specified by (32) and (33) be averted. The usefulness of these graphs rests on their compactness and on the fact that only known radar design parameters are needed to read them.

Figs. 5–9 give the probability of detection for an un-

[33] These channels can be frequency channels associated with different range gates. The sum total of identical individual channels is M.

[34] Hance, *op. cit.*, p. 23.

[35] K. Pearson, "Tables of the Incomplete Gamma-Function," Cambridge University Press, Cambridge, Eng., published by *Biometrika*; 1946.

[36] Kendall, *op. cit.*, pp. 294–297.

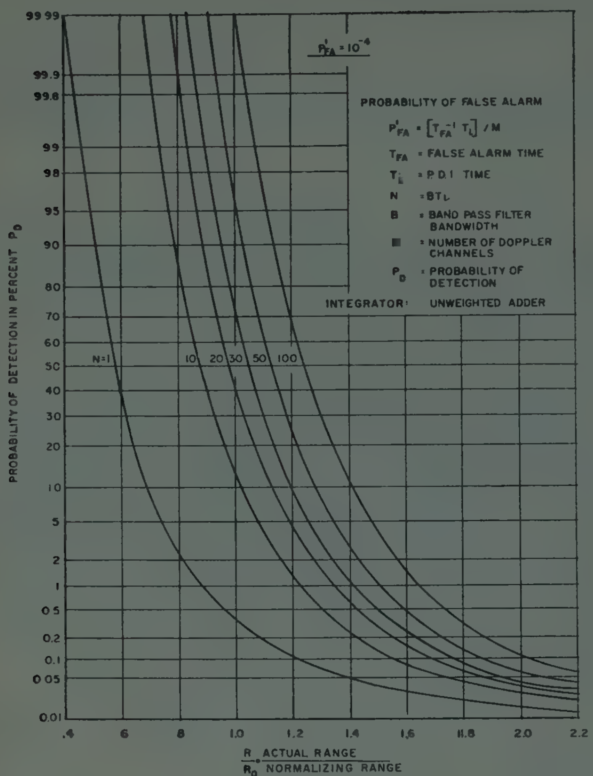

Fig. 5—Probability of detecting target at range R in terms of R/R_0.

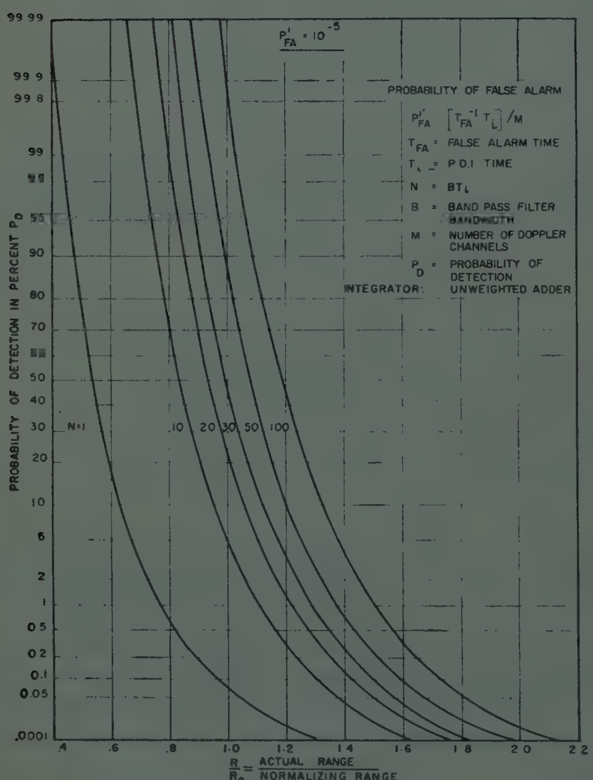

Fig. 6—Probability of detecting target at range R in terms of R/R_0.

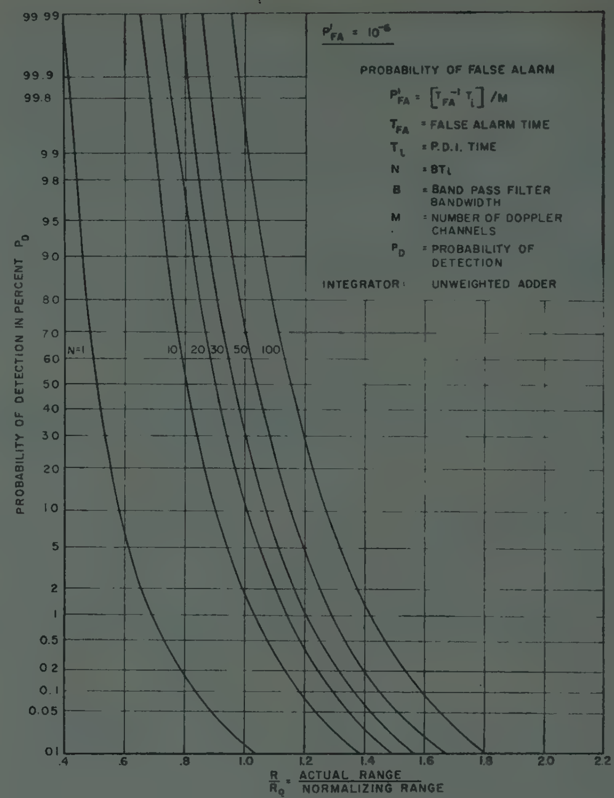

Fig. 7—Probability of detecting target at range R in terms of R/R_0.

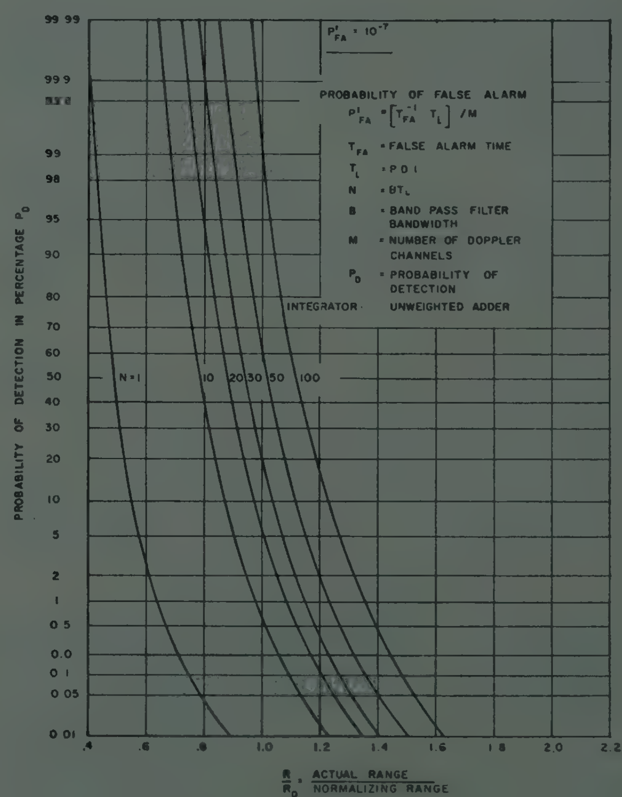

Fig. 8—Probability of detecting target at range R in terms of R/R_0.

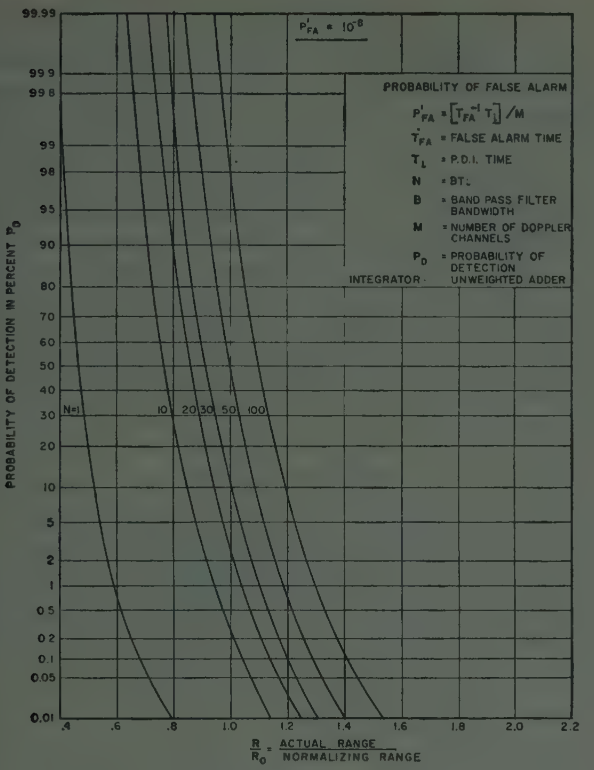

Fig. 9—Probability of detecting target at range R in terms of R/R_0.

weighted integrator as a function of R/R_0 for the probability of false alarm in a single channel, P_{FA}' of 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8} and $N=1$, $N=10$, $N=20$, $N=50$. These curves have been computed using the normal probability function tables[37] and (7), (32) and (33) for $X=0$. Examples illustrate the use of the graphs.

Example 1—Single-Channel Detection Range

Let the range for 90 per cent probability of detection be derived when radar design parameters are as follows:

False alarm time $T_{FA}=500$ seconds.
Number of channels $M=100$.
Time on target $T_i=0.05$ second.
Bandwidth of the filter $B=200$ cps.

Then from (29), $P_{FA}'=10^{-6}$. This case is given in Fig. 7. From the relation $N=BT_i$, $N=10$. On the curve $N=10$, one reads $R/R_0=0.74$ corresponding to the 90 per cent probability of detection. Hence the range R for the 90 per cent probability of detection is 0.74 R_0 where R_0 is the normalizing range given by (5).

Example 2—Effect of the Number of Channels

Suppose the problem is to compare the detection range of radars which differ from each other only in the number of Doppler filter channels M. Assume for all three radars:

Probability of detection $P_D=0.90$.
False alarm time $T_{FA}=1000$ seconds.
Time on target $T_i=0.1$ second.

Let each radar have a filter bank covering the same total Doppler bandwidth $B_0=10{,}000$ cps, where $B_0=MB$.

Let $M=10$, 100, 1000. The range $(R)_m$ corresponding to M channels is compared to the range, $(R)_{100}$, of the radar with 100 channels.

$$\frac{(R)_M}{(R)_{100}}=\frac{(R/R_0)_M}{(R/R_0)_{100}}\,\frac{(R_0)_M}{(R_0)_{100}}\,.$$

Calculations are summarized in Table I.

TABLE I

M	10	100	1000
P_{FA}'	10^{-5}	10^{-6}	10^{-7}
Fig. No.	6	7	8
B	1000	100	10
N	100	10	1
$(R/R_0)_M$	1.1	0.74	0.45
$(R/R_0)_M/(R/R_0)_{100}$	1.5	1.0	0.61
$(R_0)_M/(R_0)_{100}$	0.56	1.0	1.8
$(R)_M/(R)_{100}$	0.84	1.0	1.1

In this particular example, then, a hundredfold increase in the number of channels improves the detection range by a factor of 1.27 $(=1.1/0.84)$.

Example 3—Comparison of Pulse and Pulse Doppler Radars

Another useful example is that of comparing detection ranges of a conventional pulse radar $(R)_p$ and a pulse Doppler radar $(R)_d$, assuming equal values of average transmitted power $\overline{P}_T$.

Assume the following conditions for both radars:
Probability of detection $P_d=0.9$.
Time on target $T_i=0.02$ second.
False alarm time $T_{FA}=200$ seconds.
IF bandwidth of pulse radar $B_{IF}=5\times10^6$ cps.
Pulse repetition frequency $PRF=500$ pps.
Doppler channel bandwidth $B=500$ cps.
Number of Doppler channels $M=10$.
(Hence total Doppler bandwidth $MB=5000$ cps).

From (5) and (7), the ratio of normalizing ranges for the two radars is

$$(R_0)_p/(R_0)_d = [(B/B_{IF})(\hat{P}_T)_p/\overline{P}_T]^{1/4}.$$

If the pulse radar duty ratio is 0.001, we get

$$(R_0)_p/(R_0)_d = 0.55. \qquad (34)$$

[37] "Tables of Normal Probability Functions," Natl. Bur. of Standards, Washington, D. C., Appl. Math. Ser. 23; 1953.

Now, for the pulse radar

$$P_{FA}' = (\bar{T}_i/T_{FA}) = 10^{-4}$$
$$N = T_i \times PRF = 10.$$

Hence from Fig. 5, we read

$$(R/R_0)_p = 0.79. \tag{35}$$

For the pulse Doppler radar

$$P_{FA}' = T_i/(MT_{FA}) = 10^{-5}$$
$$N = BT_i = 10.$$

Hence from Fig. 6, we read

$$(R/R_0)_d = 0.76. \tag{36}$$

Combining (34), (35), and (36):

$$(R)_d/(R)_p = \frac{(R/R_0)_d}{(R/R_0)_p[(R_0)_p/(R_0)_d]} = 1.8.$$

Thus, in this particular example, the pulse Doppler radar has 80 per cent more detection range.

Conclusions

This paper shows how one should modify the standard radar range equation to accommodate CW and pulse Doppler radars. A method of computing the probability of detection has been developed. This method is simple and its application requires only the use of tables of normal probability functions. The approximation introduced affords sufficiently good values for the probability of detection even for a small number of integrated samples and for small values of signal-to-noise ratio, which are the most interesting and practical cases. Graphs suitable for handling a large number of typical numerical examples have been given to simplify computational problems.

Acknowledgment

Thanks are due to Dr. G. M. Nonnemaker for encouragement and guidance, to Miss Janet Heineman for the computational work, and to Profs. W. M. Siebert and J. P. Ruina for helpful comments on an earlier version of this paper.

Absorptive Filters for Microwave Harmonic Power*

VIKTOR MET†

Summary—**Utilizing the cutoff properties of certain lossy periodic waveguide structures, low reflection absorptive filters for harmonic power at microwave frequencies have been obtained.**

Various approaches to specific absorptive filters are discussed, and the experimental results presented demonstrate the validity of the concepts developed. Insertion loss of up to 50 db for second harmonic power (TE_{10} or TE_{20} mode) and less than 0.1 db for the fundamental at *S*-band could be accomplished using a waveguide filter of eight inches length. The VSWR is of the order of 1.5 or better throughout the entire useful frequency range. The wide band performance of the filters is characterized by the fact that satisfactory operation results if the frequency of the fundamental falls within the range of dominant TE_{10} mode propagation in rectangular guide, excluding the extreme edges of the band.

Introduction

THE progressive utilization of the microwave spectrum for general communication purposes brings the problem of interference more and more into the focus of attention. Thus the design of microwave filters, both on the transmitter as well as on the receiver side, has evolved as a well-controlled art[1] to fill the needs created by the increase in the number of operating systems.

The fact that all power generators used in one system also produce an appreciable amount of harmonic power results in direct interference with other systems which operate at harmonic frequencies. Thus, as a specific example, the third harmonic of an *S*-band transmitter might interfere with an *X*-band system unless the harmonics are suppressed at the source. Consequently, filters which are capable of withstanding the high power levels found in modern microwave transmitters are required to reject or absorb harmonic power.

Since the resonant elements commonly used in conventional filters lead to excessively large field strengths, evacuation of such structures becomes necessary for high power applications. On the other hand, the conventional design procedures may be modified to avoid breakdown by spreading the resonance fields as much as possible. Such approaches toward reflective high power filters have been reported by Cohn and Vogelman. Cohn[2] employs inductive irises in rectangular guide and imposes conditions that lead to equal maximum electric field strength in the cavities thus formed.

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[1] S. B. Cohn, *et al.*, "Final Report, Research on Design Criteria for Microwave Filters," Stanford Res. Inst., Palo Alto, Calif., Contract period covered March, 1955 to April, 1957, DA 36-039-SC-64625; June, 1957.

[2] S. B. Cohn, "Direct-Coupled-Resonator Filters," PROC. IRE, vol. 45, pp. 187–196; February, 1957.

This optimizes the power-handling capacity, and it is claimed that the breakdown properties of the unperturbed guide may be approached. Vogelman[3] deliberately introduces higher order mode propagation in his structure by increasing the *b*-dimension of standard rectangular waveguide. The higher order mode resonances obtained in various tapered sections produce a good filter characteristic, and the high power capabilities are reported to be excellent.

The concept of introducing perturbations in the original waveguide to obtain selectivity always suffers from the propagation of higher order modes at harmonic frequencies, which lead in turn to spurious passbands. Thus, for suppression of harmonic power, special changes in guide geometry such as ridge guide or toll-ticket guide become necessary. The number of propagating modes is minimized accordingly, and extended frequency range filters may be designed.[1] These suffer from the effects of high power breakdown, mentioned before, due to reduced dimensions.

Thus we have pointed out two disadvantages of high power reflective filters: either spurious passbands at harmonic frequencies within the range of the second and especially the third harmonic, or breakdown problems. Since most high power generators are fairly sensitive to reflections, there appears another principal difficulty for reflective filters, the elimination of which would require ferrite isolators. These in turn are not very desirable if we consider insertion loss, higher order mode propagation problems, and complexity. Consequently, for certain applications absorptive filters may be highly desirable.

The concept of the absorptive harmonic power filter has been given some thought by Edson and Cohn. Edson[4] suggests an arrangement of resonant slots on a waveguide of largely arbitrary cross section which is surrounded by lossy material, which in turn is shielded to form a closed system. This structure is quite similar to a muffler, and was named accordingly. The disadvantage of Edson's scheme is excessive attenuation of the fundamental by leakage through the slots. Cohn[5] recognizes the importance of the wall thickness to introduce cutoff properties in his structure, which otherwise is very similar to Edson's. This scheme would suffer from undesired resonances at harmonic frequencies, due both to large dimensions of the apertures in the direction of propagation, as well as to mutual coupling through the lossy region.

Although the concepts to be described in the following have been arrived at by taking an entirely different approach, that of lossy periodic structures, there is a certain amount of resemblance to the previous schemes in the appearance of the physical structures developed. Thus, they should be considered as only an extension of the basic principle described by Edson or Cohn.

The author is also aware of development efforts for absorptive ferrite filters, which have not yet been reported in detail in the literature. Therefore, it seems premature to make a comparison between such structures, and the filters to be described in the following. For this one would have to take into consideration such factors as power handling capacity, broadband performance, insertion-loss, and VSWR in the passband as well as in the stopband for the entity of propagating modes; also weight, size and, finally, cost. It is believed at this time that absorptive filters of the type to be described here offer several important advantages over corresponding ferrite structures.

Lossy Array Type Absorptive Filters

Frequency selective energy absorption in the microwave region may conveniently be accomplished by the arrangements illustrated in Fig. 1. Both Figs. 1(a) and 1(b) show a main guide propagating fundamental and harmonic power and an auxiliary guide or absorber.

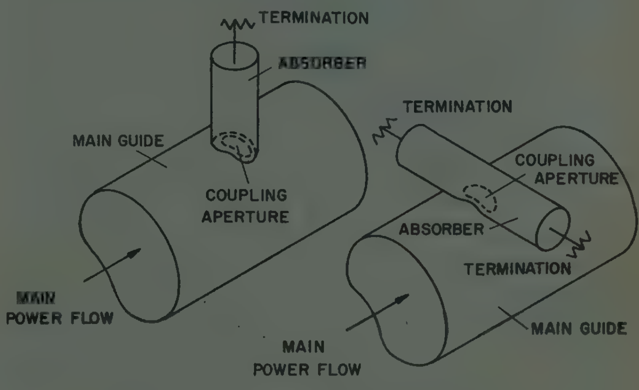

Fig. 1—Principle of harmonic absorbers.

Coupling from the main guide to the absorber is obtained through a suitably chosen aperture or apertures, designed to match the fields of the waves propagating from the main guide into the absorber. Energy entering the absorber is dissipated in a low-reflective wide band load or loads. The frequency selectivity of power dissipation in the device results from the cutoff properties of the absorber below a certain frequency, denoting the upper end of the passband of the absorptive filter.[6] Below the cutoff frequency of the absorber, the coupling apertures merely represent a reactive loading of the main guide, while at frequencies above cutoff, energy will enter the absorber to be dissipated in its load.

Two basically different principal arrangements of the absorber with respect to the main guide are illustrated

[3] J. H. Vogelman, "High-power microwave filters," IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 429–439; October, 1958.

[4] W. A. Edson, private communication.

[5] S. B. Cohn, "Microwave filter design for interference suppression," *Proc. Symp. on Electromagnetic Interference*, U. S. Army Signal Corps, pp. 230–251; June, 1958.

[6] Very recently a patent came to the author's knowledge, where these concepts are expressed quite similarly. Compare: W. L. Pritchard, *et al.*, "Selective Absorbers," U. S. Patent No. 2,869,085; January 13, 1959.

in Figs. 1(a) and 1(b). The choice of configuration will ultimately depend on the mode composition in the main guide, as well as on manufacturing techniques.

The main guide may be any type of microwave transmission line such as waveguide or coaxial line. Waveguide has to be used for the absorbers to obtain the cutoff characteristic essential for the functioning of the device. The coupling apertures have to be chosen in accordance with the fields in the main and auxiliary guide, and optimum power transfer into the absorber in the desired stopband of the filter should be aimed for. With regard to the size of the coupling apertures, it should be kept in mind that, for a flat absorption characteristic, some dimensions have to be small compared with the wavelength of the highest frequency, in order to avoid resonances. This will limit the amount of power which can be diverted into the auxiliary guide by one aperture. On the other hand, resonance apertures or the tuning of the apertures inside of the absorber may be useful to obtain maximum power transfer into the absorber and to control the frequency dependence of absorption.

Practically, a single absorber will not be sufficient to effect any substantial amount of energy dissipation in the desired stopband, and in a physical case there will always be an array of absorbers.

It is readily seen that a periodic structure consisting of a section of main guide loaded by a large number of equally spaced and oriented apertures, each coupling to its broadband-terminated absorber cell, is most advantageous in view of both the passband as well as the stopband transmission. Then we face a situation very similar to that in slow-wave circuits, which have been extensively described,[7] and which are well understood. Considering reactive as well as resistive loading of the main guide by the apertures, for the two characteristic ranges of operation, we obtain a structure with a minimum amount of electrical dissimilarity from the main guide if the circuit period is small compared with one wavelength for all frequencies to be considered.[8] Accordingly, we may expect the possibility of an extremely broadbanded transition from the main guide to the filter section.

Indeed, it turns out that even abrupt changes between periodic structure and main guide lead to VSWR values not larger than from 1.20 to 1.50 (depending on the type of structure) at frequencies below the circuit-spacing resonance, and excluding the immediate vicinity of the absorber cutoff frequency.

Depending on the choice of size and orientation of the apertures, the absorber array will cause a certain amount of attentuation per unit length in the stopband of the filter, for each propagating higher order mode. For some modes the structure will be more effective than for others, according to the specific field and aperture configurations, but all modes will be attenuated to some significant extent if absorbers are properly placed at the critical locations on the main guide.

A multitude of array compositions based on a periodic repetition of the arrangements of Figs. 1(a) and 1(b) may be prescribed. Several typical examples will be discussed in the experimental part of this paper.

Distributed Loss Absorptive Filter

In the previous section, types of filters were introduced which utilize the cutoff properties of the absorber in its usual direction of propagation. Additionally, Fig. 1 merely showed one absorber and its typical arrangement, but not the entire array. In Fig. 2, on the other hand, an absorptive filter is shown which may consist of only two coupled waveguides. As in Figs. 1(a) and 1(b), there is a main guide which provides power flow, as indicated, at both the fundamental and harmonic frequencies, and with several modes of propagation. On the other hand, the absorber is beyond cutoff for the fundamental, but propagates harmonic frequencies. The two guides are coupled by a series of apertures periodically arranged with a spacing, d. The shape of these apertures is largely arbitrary, but one dimension will always be small as compared with the dimensions of the absorber cross section.

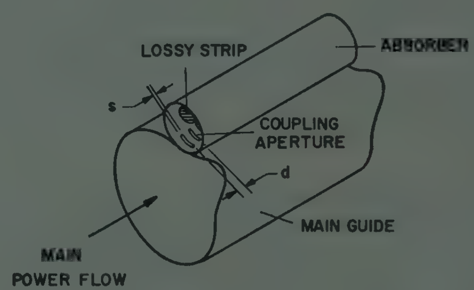

Fig. 2—Distributed loss absorptive filter.

Additionally, a strip of lossy material extends all the way along the absorber such that it is at the maximum distance from the coupling apertures. Thus the absorber provides a certain attenuation per unit length for waves propagating in its interior. (Using carbonized ceramic strips in rectangular X-band waveguide, attenuations of 4 db/cm are readily accomplished.)

Again, the spacing and size of the coupling apertures are chosen to accomplish optimum wide band power transfer from the main guide into the absorber at higher harmonic frequencies. In the passband of the filter, the periodic array of reactively loaded apertures will represent an excellent wide band structure for the fundamental. For higher harmonic frequencies which enter the absorber, the frequency sensitivity of coupling energy from the main guide will, to a large extent, depend on the loss per unit length accomplished. For appreciable attenuation between adjacent apertures, directive effects due to the accumulative interaction of the individual apertures should be negligible. To obtain good

[7] L. Brillouin, "Wave Propagation in Periodic Structures," Dover Publications, New York, N. Y.; 1953.

[8] Needless to say, this also implies good high-power performance and reduced breakdown problems, since the individual apertures represent only small perturbations of the main guide.

field matching through the apertures, the dimensions of absorber and main guide should be properly chosen with special attention to the specific modal distribution.

Since the critical width, s, of the apertures is chosen to be small with respect to the dimensions of the absorber cross section, as well as the aperture spacing, d, the nonpropagating fields of the fundamental penetrate into the absorber only a few distances, s, to any practical extent. As mentioned before, the lossy material is spaced at the maximum distance from the coupling apertures, and thus has negligible influence on the fundamental. Experiments show the validity of the principle described, which is also very attractive in view of manufacturing considerations.

Laboratory Tests on Specific Filter Structures

Grill-Type Cross Section Periodic Structures

Based on the principle outlined in Fig. 1(a), an array of rectangular guides has been constructed and is illustrated in Fig. 3. The face of the absorber-array in the photograph replaces a section of broad wall of standard rectangular S-band waveguide. The resistive card terminations in each absorber cell, visible in Fig. 3, are practically without reflection for a large range of frequencies. For reasons of convenience in mechanical construction, the dividing vane at half the distance of the S-band a-dimension extends only partially into the lossy region. The position of the absorber on the main guide is shown in Fig. 4 (further explanation to be given later). The individual absorber cells represent rectangular waveguides of the dimensions $a=1.375$ inches and $b=0.250$ inch. Accordingly, a TE_{10} cutoff frequency of 4.29 kmc results, denoting the lower limit of absorption of energy in the device. The b-dimension of the cells is chosen small as compared with a wavelength of the highest frequency of interest, *i.e.*, that of the third harmonic of S-band which lies in the X-band range. Early experiments showed that otherwise resonances appear, which are to be expected according to the theory of slow-wave circuits. (This corresponds to the well-known situation where the circuit spacing becomes of the order of half a wavelength of the propagating slow-wave.)

Transmission tests in standard S-band guide with the structure of Fig. 3 replacing a section of broad wall showed excellent VSWR performance in the passband (2.2 kmc to 4.0 kmc) and insertion loss of the order of 12 db to 15 db in the stopband (at frequencies from 5.5 kmc to 7 kmc). Insertion loss in the passband was as low as 0.03 db. For these tests only one side of the waveguide was replaced by an absorber; insertion loss of better than 20 db may be expected for a filter section of eight inches length with two absorbers (as shown in Fig. 3) on opposite broad walls.[9] High power tests have shown that the breakdown properties of the structure are excellent.

[9] V. G. Price, R. Stone, and V. Met, "Leaky wall filters for harmonic suppression," to be presented at the 1959 WESCON Convention, San Francisco, Calif.; August 18–21.

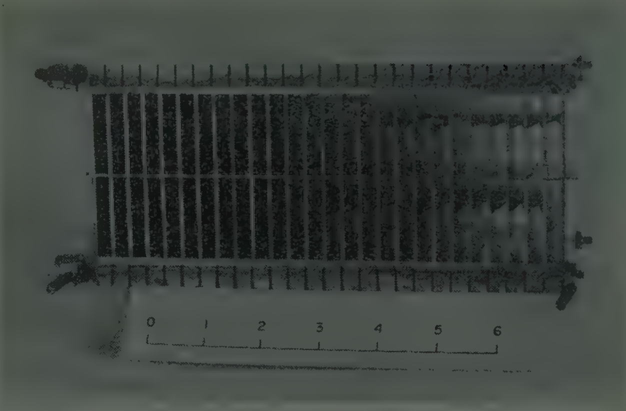

Fig. 3—Grill-type absorber array.

Fig. 4—Assembled absorptive harmonic filter.

To investigate the limits of the insertion loss obtainable for harmonic power for a prescribed length of waveguide, the b-dimension, and thus the impedance of the main guide, was reduced to render better coupling due to improved field matching into the absorber cells. This resulted in the double logarithmic cosine taper of the main guide employed in the filter shown in Fig. 4. A taper of this sort has several advantages. a) It increases the coupling to the absorber cells according to improved field matching as outlined above. Thus, for a given length of main guide, a greater amount of insertion loss for harmonic power may be accomplished. b) The dissipative structure intercepts harmonic energy more gradually, *i.e.*, there is a less abrupt change of the main guide as far as harmonic power flow is concerned. c) For harmonic power, each absorber cell is connected essentially in series with the main guide. Thus, the main guide impedance should gradually decrease in the direction of propagation to assure continuous impedance as seen by the waves to be absorbed, which situation may be approximated by a tapered section suitably chosen.

Disadvantages of the reduction of height are the increased breakdown problems and the larger VSWR for the fundamental in the passband of the filter. The main advantage is the more compact structure thus obtained.

The results of the transmission and reflection measurements in the region of the second harmonic of S-band are summarized in Fig. 5. It is apparent that, except for the range close to the cutoff of the absorber cells, the properites of the filter are quite satisfactory. Insertion loss in the passband stays below 0.1 db for frequencies up to about 3.5 kmc, and is determined on the short-circuited filter by a VSWR measurement. The increase of the insertion loss in the range from 3.5 kmc to 4 kmc is most probably due to excessive surface loss along the periodic structure, and may be reduced by improving surfaces and rounding corners. Also, a widening of the dividing vane, in order to have a narrow conducting path along the center of the absorber, should improve the situation as well as the high-power handling capabilities.

The VSWR in the passband shows a periodic variation, and thus it should be possible to further reduce reflection by a series of tuning elements appropriately located along the periodic structure. In the stopband, the VSWR is low throughout. It should be kept in mind that for the TE_{20} mode, the VSWR is measured in the E-plane arm of the folded hybrid serving as a mode launcher in conjunction with a taper. Thus the VSWR increases rapidly outside of its passband (*i.e.*, the frequency range from 4.8 kmc to 6.3 kmc). A linear taper served as a mode launcher for the TE_{10} mode; both mode launchers are shown in Fig. 6.

The insertion loss at harmonic frequencies is also plotted in Fig. 5. While the insertion loss for the TE_{20} mode remains fairly constant, at least for the frequency range of the measurements, that for the TE_{10} mode decreases gradually above the TE_{30} cutoff of the main guide. This may be explained with the following simple logic. As mentioned before, the absorber replaces a section of main guide broad wall, and the fields have to propagate along a structure, as sketched in Fig. 7. If a TE_{n0} mode propagates in the main guide, it is conceivable that the nature of the fields in the section with the periodic structure does not change drastically, although it can no longer be called a waveguide mode. Thus, modes of odd symmetry like the TE_{20} should couple better to the absorber cells than modes of even symmetry since the dividing vane presents less of a perturbation. For modes of odd symmetry, we may introduce a center dividing vane in the main guide without disturbing the fields, and this should also be reasonably true in the periodic structure. Then, our problem may be resolved into that of propagation in two separate waveguides and periodic structures, which phenomenon has been extensively studied. Since the absorber cells are all assumed to be terminated in their characteristic impedance, a much simpler situation results than in the case of the usual slow-wave circuit with reactive terminations. By the simplified analogy to the case of a plane wave over an array of semi-infinite parallel plates, it may then be stated that, theoretically, there is no propagation along the periodic structure. Practically,

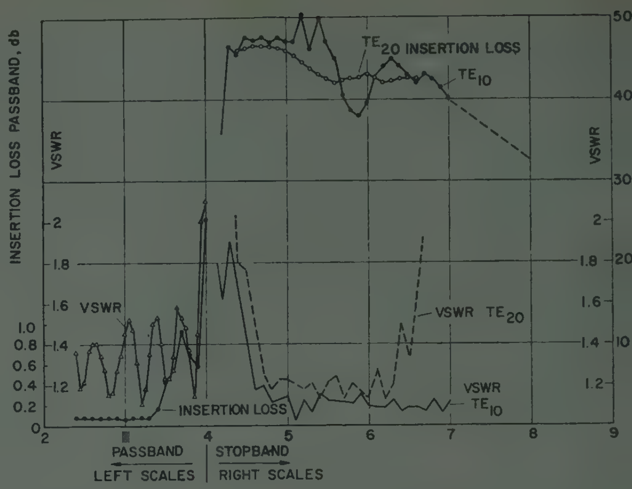

Fig. 5—Transmission characteristic of the filter shown in Fig.

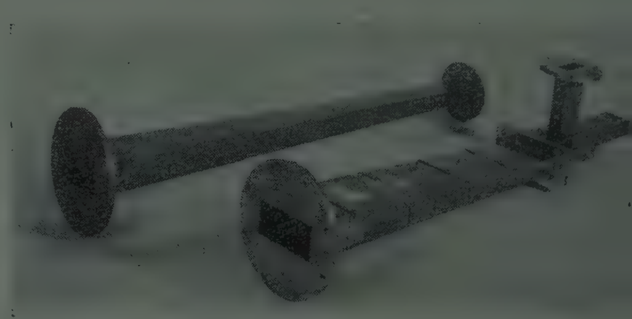

Fig. 6—Mode launchers for the TE_{10} and TE_{20} modes.

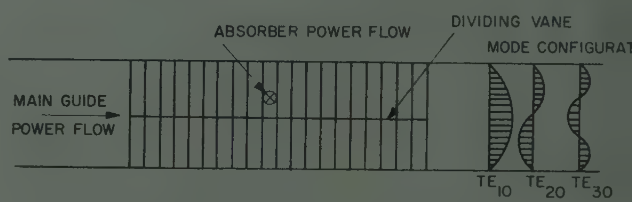

Fig. 7—Cross-sectional view of the absorber.

this is almost true, as illustrated by the insertion lo exceeding 40 db for an absorber extending eight inch along the main guide. For modes of even symmetry, t presence of the center vane will be of appreciable infl ence, and it is conceivable that at high frequencies t periodic structure will support a mode of propagati with large field concentration along the center vane a a corresponding reduction of coupling to the individu absorber cells. This seems to be the cause of the redu tion in insertion loss for the TE_{10} mode at higher fr quencies above 7 kmc.

Transmission at higher frequencies was checked the crude but satisfactory method of launching and r ceiving with ordinary X-band waveguide detect mounts. Insertion loss of about 30 db to 35 db could observed at frequencies above 7 kmc, for symmetric as well as asymmetrical excitation and pickup. For fr quencies above the TE_{30} mode cutoff in the main guid a varying amount of the TE_{10} to TE_{30} mode conversi from input to output could be observed. This is pro ably due to the fact that there is strong coupling, by w

of the apertures of the individual absorber cells, between TE_{10} and TE_{30} type fields in the periodic structure. A periodic structure with three rows of absorber cells may exhibit different behavior and, due to the absence of a center vane effect, might also render better insertion loss at higher frequencies.

No experimental data are available at present to illustrate the absorber properties of the grill-type cross section structures for other modes than that of the TE_{n0} type. All measurements have to be somewhat specialized or even crude at this stage of investigation, since reasonably accurate measurements of transmission and reflection for frequencies including the third harmonic are complex and costly. A multiple probe measurement and analysis would have to be performed[10,11] which, in order to include reflection and mode conversion, would involve a complex programming scheme for a digital computer.

Special structures like the double logarithmic cosine taper used for the filter of Fig. 4 will, by themselves, suppress a number of modes due to the change in guide geometry. Fig. 8 shows the respective cutoff frequencies for a typical example. Little is known about the percentage of conversion and reflection of higher order modes incident to such a change of geometry.

The grill-type structure combined with the double cosine taper also presents a fairly simple case, with three different modes at the most, for the frequency range of interest. Thus the cutoff region in Fig. 5 can be examined quite carefully. Only two mode launchers are needed for frequencies up to about 7 kmc, and measurements with a cross-guide sliding probe in the main guide show good agreement with the theoretical field distributions at higher harmonic frequencies, for both the TE_{10} and the TE_{20} mode.

Distributed Loss Absorptive Filter

For this type of filter the case of rectangular waveguide, both for the main guide as well as the absorber, is of particular interest.

Preliminary tests were conducted by placing lossy strips into standard slotted waveguide sections and directly measuring the attenuation per unit length by means of the probe. Carbonized ceramic strips were found to be a material excellently suited for the purpose, especially in view of eventual operation in a hard vacuum. In X-band waveguide, for a strip with a 0.5 inch $\times$0.125 inch cross section, the attenuation per centimeter obtained is tabulated below.

f	8	8.5	9	9.5	10	kmc
Attenuation	[illegible]	3	4	4.5	5.5	db/cm

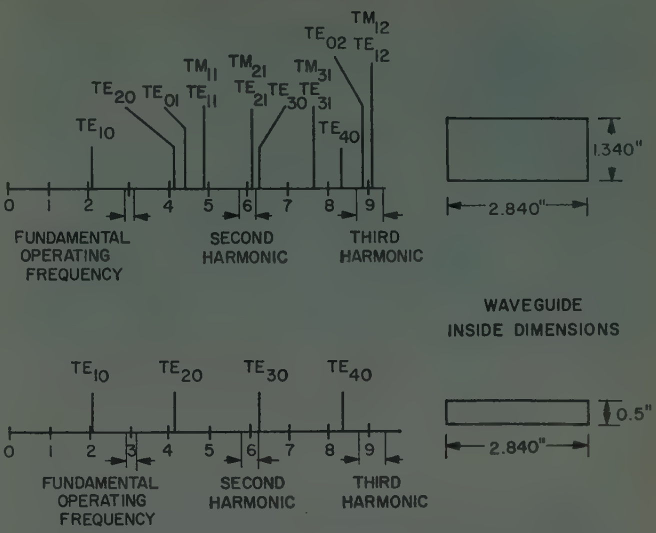

Fig. 8—Higher order mode cutoff frequencies for different cross sections of rectangular waveguide.

From these values one can roughly estimate the amount of aperture interaction to be expected for each specific spacing, d (Fig. 2).

Using the double cosine taper available from previous experiments, the filter illustrated in Figs. 9 and 10 was constructed. Note the absorber design and the lossy strips in position in Fig. 9, with a single absorptive strip placed outside for comparison. The assembled filter is shown in Fig. 10.

Fig. 11 demonstrates the performance of the filter. The over-all transmission characteristic for the fundamental as well as the third harmonic[12] is characterized by very low VSWR. The insertion loss for the fundamental is seen to be better than 0.1 db for a large range. For this, again a VSWR measurement of the short-circuited filter was employed.

The influence of the presence of the lossy strips on the fundamental was also investigated. Measurements of the short-circuited filter, with and without lossy strips, were practically identical and showed minor difference only above 3.5 kmc. Thus the validity of the basic concept was established by an exact method: the fundamental does not penetrate to the lossy strips to any practical extent for the proper dimensions of the apertures and the absorber cross section.

The desired insertion loss occurs at frequencies of the third harmonic according to the particular absorber configuration of the filter, shown in Figs. 9 and 10. Although the structure is by far not as effective as the one described previously, it has definite merit from the manufacturing point of view. At harmonic frequencies, the apparent decrease of the insertion loss with frequency, as observed in Fig. 11, is not yet completely understood. Most probably this occurs due to the fact that the impedance as well as the guide wavelength of the

[10] M. P. Forrer and K. Tomiyasu, "Determination of higher order propagating modes in waveguide systems," *J. Appl. Phys.*, vol. 29, pp. 1040–1045; July, 1958.

[11] V. G. Price, "Measurement of harmonic power generated by microwave transmitters," IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 116–120; January, 1959.

[12] In Fig. 11, the VSWR grid lines for the stop band should be labeled analogously to those for the pass band.

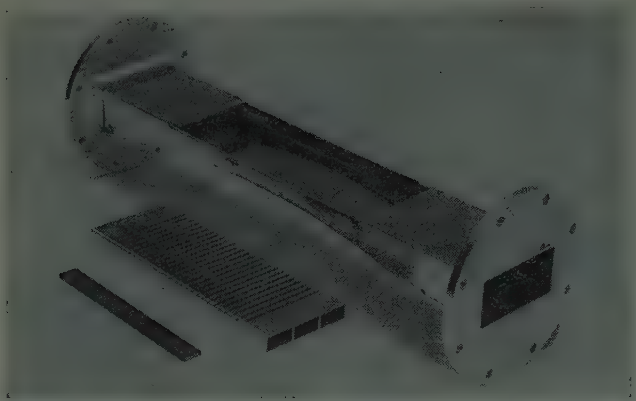

Fig. 9—Disassembled double cosine tapered distributed loss harmonic filter for the third harmonic.

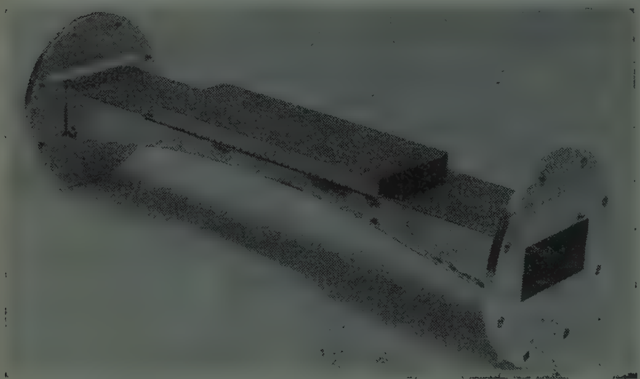

Fig. 10—Assembled filter.

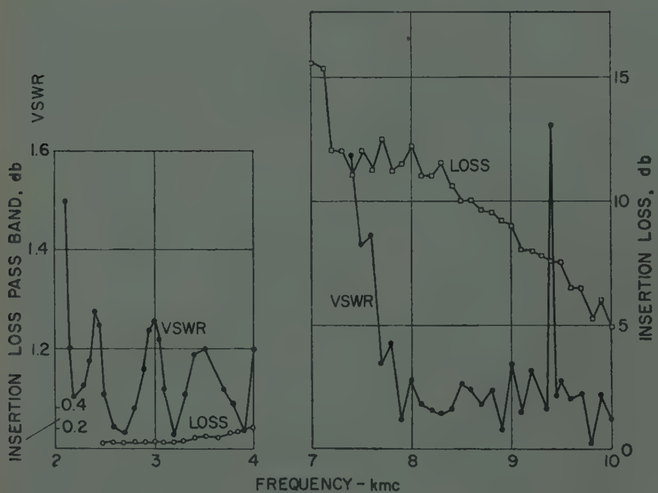

Fig. 11—Transmission characteristic of the absorptive filter shown in Figs. 9 and 10, TE_{10} mode.

secondary guide increase considerably when approaching cutoff conditions.

Geometric Configurations for Absorptive Filters

Various arrangements for absorptive filters which are based on the principles outlined in the previous sections are sketched in Fig. 12. They are briefly discussed in consecutive order in the following paragraph.

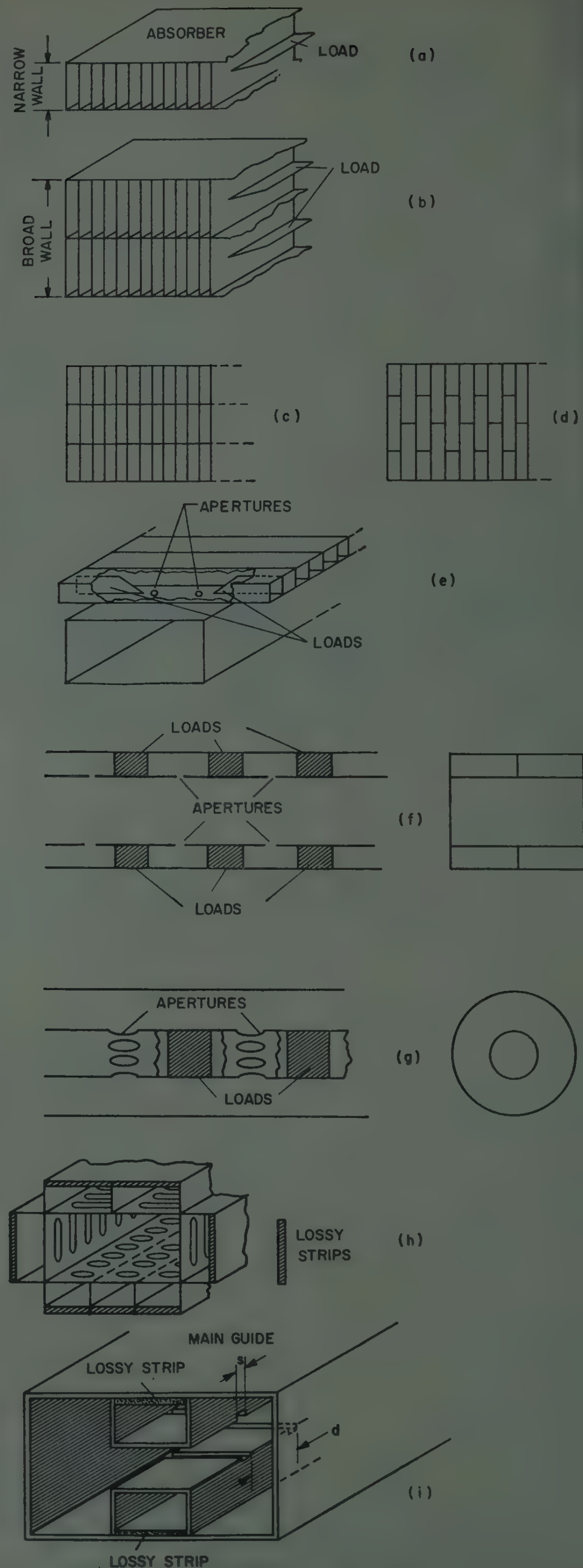

Fig. 12—Absorber configurations.

Figs. 12(a)–12(d) illustrate the grill-type cross section absorber type filter with locations on broad or narrow walls of the main guide. Figs. 12(c) and 12(d) merely show the cross sections, and one can think of a large variety of combinations of these and other basic types of structures on all four sides of rectangular guide. Corresponding structures may be designed for a main guide which is not rectangular. Fig. 12(e) illustrates an absorber arrangement based on cross-guide coupling, resulting from Fig. 1(b).

The principle of periodic loading, which is also based on the arrangement of Fig. 1(b), is illustrated by Figs. 12(f) and 12(g). The former shows a combination of rectangular guides, the other shows a coaxial system with a circular guide which serves as a center conductor and an absorber. The loads are sufficiently remote from the apertures to utilize the absorber cutoff properties at the fundamental. Finally, the isometric views of Figs. 12(h) and 12(i) demonstrate a possible configuration of lossy strip absorbers with slot type apertures on the main guide. Again, one can think of a variety of combinations of absorbers.

Conclusion

The theoretical investigations have led to three basically different types of structures for absorptive filters. All three utilize the cutoff properties of waveguide to achieve power transfer into an absorber at high frequencies, with negligible loss for the lower frequencies to be propagated in the main guide. Experimental investigations on several typical structures have been conducted which show the validity of the suggested schemes. Satisfactory match and very low insertion loss in the pass band, and low-reflection absorption of energy in the stop band were demonstrated. Such filters thus lend themselves readily to be incorporated in high-power systems, for purposes of harmonic suppression and ininterference reduction.

Since many practical higher order mode problems result from resonance effects, loading of the particular section of "main guide" (in a very general sense) with a very simple absorptive filter of low insertion loss, *i.e.*, a "harmonic pad," will eliminate such problems completely. Especially when located close to or within the generator, such a pad will sufficiently load all resonances at harmonic frequencies. For example, these may otherwise trigger off a high power breakdown in a system operated close to its power-carrying capabilities for the fundamental.

Thus, it appears that absorptive filters of the type described should find various applications in present and future high power system and tube design at microwave frequencies. Although the experiments reported here are of a somewhat specialized nature, taking into account only the TE_{10}, TE_{20}, and TE_{30} modes in rectangular waveguide, it is believed that the principles developed are most readily applicable to more general modal configurations.

Simple Methods for Computing Tropospheric and Ionospheric Refractive Effects on Radio Waves*

S. WEISBROD†, MEMBER, IRE, AND L. J. ANDERSON†

Summary—**The paper describes a simple and accurate method for computing ionospheric and tropospheric bending. The only assumptions made are that the refractive gradient is radial and that the refractive index profile can be approximated by a finite number of linear segments whose thickness is small compared with the earth's radius. These assumptions are readily justifiable in all practical cases. Since there are no limitations on the angle of elevation and the shape of the refractive index profile, the method has a wide application and it is extended to cover other refractive effects such as retardation, Doppler error and Faraday Rotation.**

Introduction

THE bending of radio waves passing through the troposphere and ionosphere has aroused considerable interest in recent years. Such bending bears directly on the accuracy of tracking radio stars, satellites, missiles and other high-altitude objects. This problem has been attacked by a number of investigators and several different methods have been developed.[1–6] Most of these, however, are either of limited accuracy or too laborious for routine application where both speed and accuracy are required.

A method is presented in this paper which is particularly simple and which can be applied to both tropospheric and ionospheric bending. There are no limitations on the shape of the profile or angle of elevation. The only assumptions are that the refactive index gradient is only in the vertical plane, that the index of refraction profile can be approximated by a number of linear segments, and that the thickness of these steps is small compared to earth's radius. Since these assumptions are readily justifiable in all practical cases, the method has a wide application.

In addition to refractive bending, the closely related problem of signal retardation is also considered and a simple approximate method, analogous to the one used for computing the bending, is developed.

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Development of the Method

Referring to Fig. 1, consider a ray entering at angle β an infinitesimal layer of thickness $d\rho$. Since the curvature of the ray is equal to the component of the refractive gradient normal to the ray, divided by the index of refraction, it follows that:

$$\frac{1}{K} = \frac{1}{n}\frac{dn}{d\rho}\cos\beta \qquad (1)$$

where K is the radius of curvature.

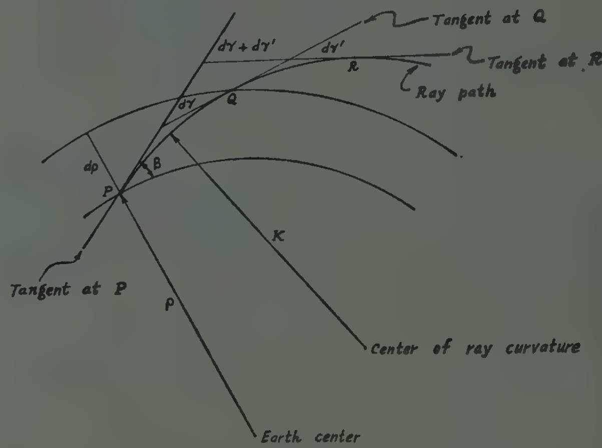

Fig. 1—Geometry of bending through an infinitesimal layer.

The length of the ray path in the layer is

$$K d\gamma = \csc\beta d\rho \qquad (2)$$

which, combined with (1), gives

$$d\gamma = \frac{1}{n}\frac{dn}{d\rho}\cot\beta d\rho. \qquad (3)$$

Since $d\gamma$'s of all elementary layers are directly additive, as shown in Fig. 1, by considering $d\gamma'$ due to bending between points Q and R, it follows that the contribution to the total bending γ, due to a layer bounded by the heights ρ_j and ρ_k is

$$\gamma_{jk} = \int_{\rho_j}^{\rho_k} \frac{1}{n}\frac{dn}{d\rho}\cot\beta d\rho. \qquad (4)$$

If the ray departs from the earth's surface with the elevation angle of α_0, Snell's Law for spherical stratification states:

$$n_0 a \cos\alpha_0 = n\rho\cos\beta = \text{constant} \qquad (5)$$

where

n_0 = surface index of refraction,
a = Earth's radius,
$\rho = a + h$,
h = height above earth,
n = index of refraction at the specified height.

From (5) we get

$$\cos\beta = (n_0 a/n\rho)\cos\alpha_0 = (n_j\rho_j/n\rho)\cos\beta_j \tag{6}$$

$$\begin{aligned}\sin\beta &= (n_0 a/n\rho)\left[(n\rho/n_0 a)^2 - \cos^2\alpha_0\right]^{1/2}\\ &= (n_j\rho_j/n\rho)\left[(n\rho/n_j\rho_j)^2 - \cos^2\beta_j\right]^{1/2}\end{aligned} \tag{7}$$

$$\begin{aligned}\cot\beta &= \left[(n\rho/n_0 a)^2 - \cos^2\alpha_0\right]^{-1/2}\cos\alpha_0\\ &= \left[(n\rho/n_j\rho_j)^2 - \cos^2\beta_j\right]^{-1/2}\cos\beta_j\end{aligned} \tag{8}$$

where n, ρ and β are the values of these parameters at some height h.

Eq. (8) can be substituted in (4) to give the general equation for refractive bending.

$$\begin{aligned}\gamma_{jk} &= \int_{\rho_j}^{\rho_k} \frac{1}{n}\frac{dn}{d\rho}\frac{\cos\alpha_0}{\left[(n\rho/n_0 a)^2 - \cos^2\beta_j\right]^{1/2}}\,d\rho\\ &= \int_{\rho_j}^{\rho_k} \frac{1}{n}\frac{dn}{d\rho}\frac{\cos\beta_j}{\left[(n\rho/n_j\rho_j)^2 - \cos^2\beta_j\right]^{1/2}}\,d\rho.\end{aligned} \tag{9}$$

We now assume that a) $dn/d\rho = -k$ = constant, b) $\rho_k - \rho_j \ll \rho_j$, and c) index of refraction n is very nearly equal to unity. On the basis of these assumptions we can write:

$$k = \frac{(N_j - N_k)\times 10^{-6}}{\rho_k - \rho_j} = \frac{(N_j - N)\times 10^{-6}}{\rho - \rho_j} \tag{10}$$

where $N = (n-1)\times 10^6$

$$\begin{aligned}(n\rho/n_j\rho_j)^2 &= \left\{\left[1 - (N_j - N)\times 10^{-6}\right]\left[1 + (\rho - \rho_j)/\rho_j\right]\right\}^2\\ &\cong 1 + 2(\rho - \rho_j)(1 - k\rho_j)/\rho_j\end{aligned} \tag{11}$$

and, substituting in (9) we get

$$\begin{aligned}\gamma_{jk} &= k\cos\beta_j \int_{\rho_j}^{\rho_k}\left[\sin^2\beta_j + 2(\rho - \rho_j)(1 - k\rho_j)/\rho_j\right]^{-1/2} d\rho\\ &= \frac{k\rho_j\cos\beta_j}{1 - k\rho_j}\left\{\left[\sin^2\beta_j + 2(\rho_k - \rho_j)(1 - k\rho_j)/\rho_j\right]^{1/2} - \sin\beta_j\right\}.\end{aligned} \tag{12}$$

From (6), (7), and (11)

$$\begin{aligned}\sin\beta_k &= (n_j\rho_j/n_k\rho_k)\left[(n_k\rho_k/n_j\rho_j)^2 - \cos^2\beta_j\right]^{1/2}\\ &= (\cos\beta_k/\cos\beta_j)\left[\sin^2\beta_j + 2(\rho_k - \rho_j)(1 - k\rho_j)/\rho_j\right]^{1/2}.\end{aligned} \tag{13}$$

Combining with (12)

$$\gamma_{jk} = \frac{k\rho_j\cos^2\beta_j}{1 - k\rho_j}(\tan\beta_k - \tan\beta_j). \tag{14}$$

From (6), 10), and (11)

$$\begin{aligned}\frac{k\rho_j}{1 - k\rho_j} &= \frac{2(N_j - N_k)\times 10^{-6}\sec^2\beta_j}{\sec^2\beta_k - \sec^2\beta_j}\\ &= \frac{2(N_j - N_k)\times 10^{-6}\sec^2\beta_j}{\tan^2\beta_k - \tan^2 B_j}\end{aligned} \tag{15}$$

which, substituted in (14), gives the desired expression for γ_{jk}

$$\begin{aligned}\gamma_{jk} &= \frac{(N_j - N_k)\times 10^{-6}}{\frac{1}{2}(\tan\beta_j + \tan\beta_k)}\\ &= \frac{N_j - N_k}{500(\tan\beta_j + \tan\beta_k)}\text{ milliradians}\end{aligned} \tag{16}$$

where N is expressed in N units, $(n-1)\times 10^6$.

Total bending through the atmosphere is simply the sum of individual contributions.

$$\gamma(mr) = \sum_{k=0}^{n-1}\frac{(N_k - N_{k+1})}{500(\tan\beta_k + \tan\beta_{k+1})}. \tag{17}$$

Refractive Bending Referred to Earth Center

It is frequently convenient to measure the refractive error in terms of the angle subtended from the earth's center. This quantity, denoted by ϵ, can be readily obtained from Fig. 2.

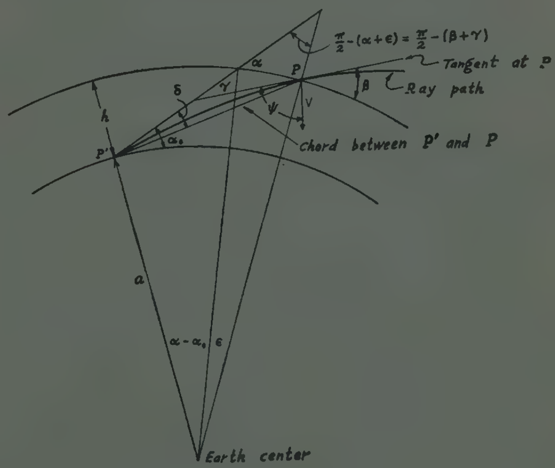

Fig. 2—Geometry of bending through a refractive layer.

$$\epsilon = \gamma - (\alpha - \beta). \tag{18}$$

The quantity $\alpha - \beta$ may be conveniently found in the following manner. From Snell's law we have

$$n_0\cos\alpha = n\cos\beta$$

or

$$\begin{aligned}\cos\beta &= \cos\left[\alpha - (\alpha - \beta)\right]\\ &= \left[1 + (N_0 - N)\times 10^{-6}\right]\cos\alpha\end{aligned} \tag{19a}$$

$$\begin{aligned}\cos\alpha &= \cos\left[\beta + (\alpha - \beta)\right]\\ &= \left[1 - (N_0 - N)\times 10^{-6}\right]\cos\beta.\end{aligned} \tag{19b}$$

Expansion of (19) and the application of small angle approximations results in

$$\alpha-\beta=\{1-[1-2(N_0-N)\times 10^{-6}\cot^2\alpha]^{1/2}\}\tan\alpha \quad (20a)$$

$$=\{[1+2(N_0-N)\times 10^{-6}\cot^2\beta]^{1/2}-1\}\tan\beta. \quad (20b)$$

At heights above the troposphere for rays departing tangentially, or for angles of elevation greater than 100 milliradians at any height, α and β are very nearly equal and (20) reduces to:

$$\alpha-\beta\cong(N_0-N)\times 10^{-6}\cot\alpha$$

$$\cong(N_0-N)\times 10^{-6}\cot\beta. \quad (21)$$

Elevation Angle Error

In most practical applications the quantity of greatest interest is the elevation angle error. This quantity denoted by δ can be obtained from Fig. 2 by the use of the law of sines.

$$a\cos\alpha_0=\rho\cos\alpha$$

$$a\cos(\alpha_0-\delta)=\rho\cos[(\alpha+\epsilon)-\delta]. \quad (22)$$

From (22) we get

$$\tan\delta=\frac{\sin\epsilon\tan\alpha+(1-\cos\epsilon)}{\sin\epsilon+\cos\epsilon\tan\alpha-\tan\alpha_0}$$

or

$$\delta=\frac{\epsilon\tan\alpha+\epsilon^2/2}{\epsilon+\tan\alpha-\tan\alpha_0}. \quad (23)$$

From (5), (18), and (22) an alternate form of (23) may be obtained

$$\delta=\frac{\gamma\tan\beta-(N_0-N)\times 10^{-6}+\gamma^2/2}{\gamma+\tan\beta-\tan\alpha_0}. \quad (24)$$

Omitting $\epsilon^2/2$ in the numerator of (23) results in an error of about five per cent in the troposphere for a tangentially departing ray. At higher angles of elevation or greater heights, this error becomes negligible.

It should be noted that whereas γ and ϵ, due to the passage of the ray through various layers, are directly additive, δ's are not. Thus, to evaluate δ at ionospheric heights or above, it is first necessary to combine the tropospheric and the ionospheric ϵ's or γ's and then use (23) or (24). However, it turns out that in nearly all practical cases above the troposphere $\epsilon^2/2\ll\epsilon$ and $\epsilon\ll\tan\alpha-\tan\alpha_0$; consequently the omission of $\epsilon^2/2$ in the numerator and ϵ in the denominator usually results in less than five per cent error at F region heights.

Eq. (23) may thus be approximated by

$$\delta=\frac{\epsilon\tan\alpha}{\tan\alpha-\tan\alpha_0}. \quad (25)$$

It is, therefore, usually justifiable to add directly the tropospheric and ionospheric δ's to obtain the total elevation angle error.

At astronomical distances all three quantities (γ, ϵ and δ) become numerically equal.

Doppler Error

Due to the refractive bending, there will generally be an error in the measurement of the radial component of the target velocity. The equation describing this can be readily derived with the aid of Fig. 2. Let V be the component of the target velocity in a plane determined by the transmitter beam and the earth's center. If ψ is the angle between V and the apparent direction, then the following statements can be made:

a) measured radial velocity is

$$V_m=V\cos\psi, \quad (26)$$

b) true radial velocity

$$V_r=V\cos[\psi-(\gamma-\delta)], \text{ and} \quad (27a)$$

c) apparent radial velocity

$$V_a=V\cos(\psi-\delta). \quad (27b)$$

Since γ and δ are at most on the order of a few milliradians, expansion of (27) using the usual small angle approximations results in

$$V_a-V_m=\Delta V_a=V\gamma\sin\psi \quad (28a)$$

$$V_r-V_m=\Delta V_r=V(\gamma-\delta)\sin\psi. \quad (28b)$$

The quantity which is usually of interest is ΔV_r, although for some applications ΔV_a may be the more convenient to use since beyond the refractive regions it is independent of height and range.

Retardation of the Signal Passing Through a Region of a Constant Refractive Gradient

Signal retardation $d\tau$ caused by a layer of thickness $d\rho$ (Fig. 1) is given by

$$d\tau=(1/v-1/c)\csc\beta d\rho$$

$$=(c/v-1)\csc\beta d\rho/c=N\times 10^{-6}c^{-1}\csc\beta d\rho \quad (29)$$

where c and v are signal velocities in free space and the medium, respectively.

The range error is given by

$$\Delta r_{jk}=\int_{\rho_j}^{\rho_k}c\,d\tau=\int_{\rho_j}^{\rho_k}\frac{N\times 10^{-6}d\rho}{\sin\beta}. \quad (30)$$

In evaluating γ we found (16)

$$\gamma_{jk}=\int_{\rho_j}^{\rho_k}\frac{(dn/d\rho)d\rho}{\tan\beta}=\int_{\rho_j}^{\rho_k}\frac{dn}{\tan\beta}=\frac{(N_j-N_k)\times 10^{-6}}{\frac{1}{2}(\tan\beta_j+\tan\beta_k)}.$$

In other words, the value of the integral for the case of a constant radial gradient was found to be very nearly equal to the one that would have been obtained had we taken the average value of the denominator of the integrand and treated it as a constant. We are therefore tempted to treat the integral of (30) in a similar manner. Furthermore, we can argue that at low angles sine and

tangent are nearly the same and at high angles the rate of change of sin β is so slow that such procedure is certainly justifiable.

Thus we evaluate (30) by setting

$$\Delta r_{jk} = \int_{\rho_j}^{\rho_k} \frac{N \times 10^{-6} d\rho}{\sin \beta} = \frac{2 \times 10^{-6}}{\sin \beta_j + \sin \beta_k} \int_{\rho_j}^{\rho_k} N d\rho,$$

but from (10)

$$\int_{\rho_j}^{\rho_k} N d\rho = \int_{\rho_j}^{\rho_k} [N_j - k(\rho - \rho_j)] d\rho$$
$$= N_j(\rho_k - \rho_j) - \tfrac{1}{2}(N_j - N_k)(\rho_k - \rho_j)$$
$$= \tfrac{1}{2}(N_j + N_k)(\rho_k - \rho_j).$$

Substituting in (30) we get

$$\Delta r_{jk} = \frac{(N_k + N_j)(\rho_k - \rho_j) \times 10^{-6}}{\sin \beta_k + \sin \beta_j}. \tag{31}$$

To compute retardation for a double passage through the layer, (31) must be doubled.

The integral of (30) can be evaluated exactly. The resulting expression, however, is quite involved. Comparison of the exact solution with (31) indicates an error of a few hundredths of one per cent for the case of the tropospheric propagation. In the ionosphere, the errors are somewhat larger, although still sufficiently small to justify the use of (31). This is discussed in more detail in the section on Application to the Ionosphere.

Application to the Troposphere

In computing the refractive effects of the troposphere, one normally uses radiosonde data in which the temperature, pressure, and dewpoint are given at "significant" levels above the earth's surface. These levels have been selected so that linear interpolation between adjacent levels is a good approximation to the measured temperature and dewpoint profiles. The refractivity N at each significant level is computed from the expression

$$N = (n - 1) \times 10^{-6} = (77.6/T)(P + 4810e/T)$$

where

n = refractive index,
T = absolute temperature in degrees Kelvin,
P = total atmospheric pressure in millibars,
e = water vapor pressure in millibars.

The index of refraction is virtually independent of frequency up to 30,000 megacycles.

To compute the refractive bending we tabulate $N_0 - N$ at significant levels and use (17).

$$\gamma = \sum_{k=0}^{n-1} \frac{N_k - N_{k+1}}{500(\tan \beta_k + \tan \beta_{k+1})} \text{ milliradians.}$$

The above expression is quite exact for the bending in a layer of constant gradient as long as the layer thickness is small compared with the earth's radius. For a layer thickness of 50,000 feet, which is much greater than ever found in the troposphere, the error is less than 0.06 per cent.

To determine the various β's in terms of the angle of elevation α_0 and height h, we use Snell's Law, (5),

$$\cos \beta_h = \frac{\cos \alpha_0}{(1 + h/a)[1 - (N_0 - N) \times 10^{-6}]}.$$

We note that β, the ray inclination angle, is a function only of height h and the difference in the refractive index between the surface and h. It is independent of the shape of the refractive profile. This fact allows us to determine β_h at each significant level independently of other levels. Thus, it is not necessary to start at the surface and work up layer by layer as is necessary in many other computation methods.

Fig. 3 is a graphical representation of Snell's Law

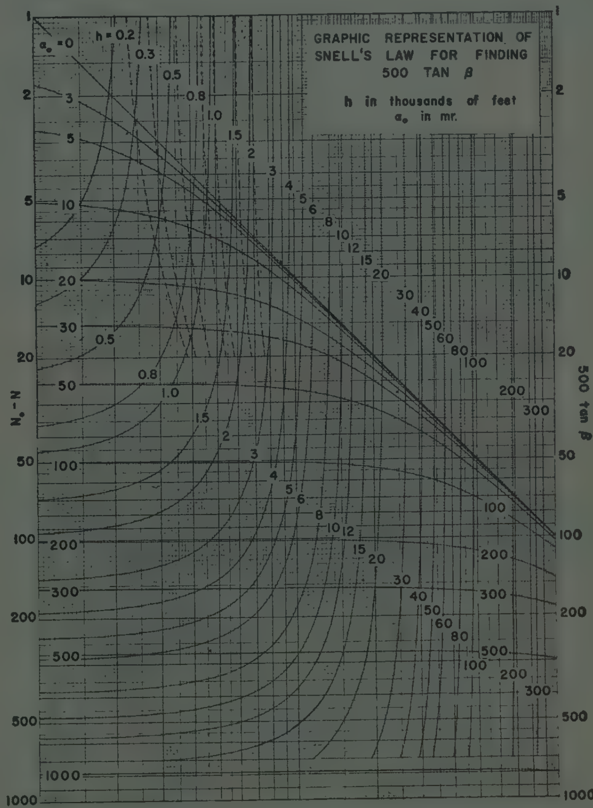

Fig. 3

from which 500 tan β may be read off directly. The procedure in using the plot is as follows. Enter on the left margin at the appropriate $N_0 - N_h$. Proceed horizontally to the proper height, interpolating between curves if necessary. Use the solid height curves when $N_0 - N_h$ is positive and the dashed curves when $N_0 - N_h$ is negative. Then proceed vertically to the assumed α_0 and read off 500 tan β along the right margin.

Suppose, for example, that $h = 4500$ feet and $N_0 - N_h$ is 58 units and $\alpha_0 = 0°$. Enter the left margin at 58, move to the right to $h = 4500$ (midway between 4000 and 5000 feet height curves), then move up vertically to $\alpha_0 = 0$ line and

read 500 tan $\beta = 8.7$ on the right margin. If α_0 were 50 milliradians instead of 0, 500 tan $\beta = 26.5$.

A convenient procedure for computing-ray bending for a given refractive index profile is as follows.

1) Tabulate N, $N - N_0$ and h at each significant level.
2) Find 500 tan β_h at each level using chart of Fig. 3.
3) For each adjacent pair of levels use (16) to determine $\Delta\gamma$'s.
4) Add $\Delta\gamma$'s from the surface up to the height at which total tropospheric bending is desired.
5) To obtain refractive error referred to the observer use (24),

$$\delta = \frac{\gamma \tan \beta - (N_0 - N) \times 10^{-6} + \gamma^2/2}{\gamma + \tan \beta - \tan \alpha_0}.$$

At greater heights or higher angles of elevation, the alternate form of (24); *i.e.*, (23) will be found more convenient.

$$\delta = \frac{\epsilon \tan \alpha + \epsilon^2/2}{\epsilon + \tan \alpha - \tan \alpha_0}$$

where ϵ may be obtained from (18) and (21).

Cot β may be obtained from Fig 3. For ionospheric heights and above, cot α may be obtained from Fig. 5. If ϵ has been calculated, δ may be approximately evaluated from Fig. 6, which is a graphic representation of (25).

Atmospheric retardation in any one layer may be computed from (31).

$$\Delta r_{jk} = \frac{(N_k + N_j)(h_k - h_j)}{1000(\sin \beta_k + \sin \beta_j)}$$

where Δr_{jk} is the range error for one-way passage through the layer. 1000 sin β can be obtained from Fig. 4 in a manner analogous to that of obtaining 500 tan β from Fig. 3. Height is expressed in thousands of feet and Δr_{jk} is expressed in feet. Values of Δr for a passage through the troposphere at zero elevation angle are on the order of 350 feet.

The Doppler error for targets in or above the troposphere but below the ionosphere can be readily computed from (28).

For a standard atmosphere at the height of 100,000 feet and $\alpha_0 = 0$ assuming $\Psi = 90°$, the Doppler error is on the order of one-half per cent.

Application to the Ionosphere

In considering the effect of the ionosphere on the passage of electromagnetic waves, we will limit ourselves to frequencies above 100 mc, since this represents the situation of most interest and also will enable us to be simplify the various equations.

The force exerted by a plane electromagnetic wave on an electron of mass m and charge e, in the presence of a steady magnetic field $\boldsymbol{B}$, is

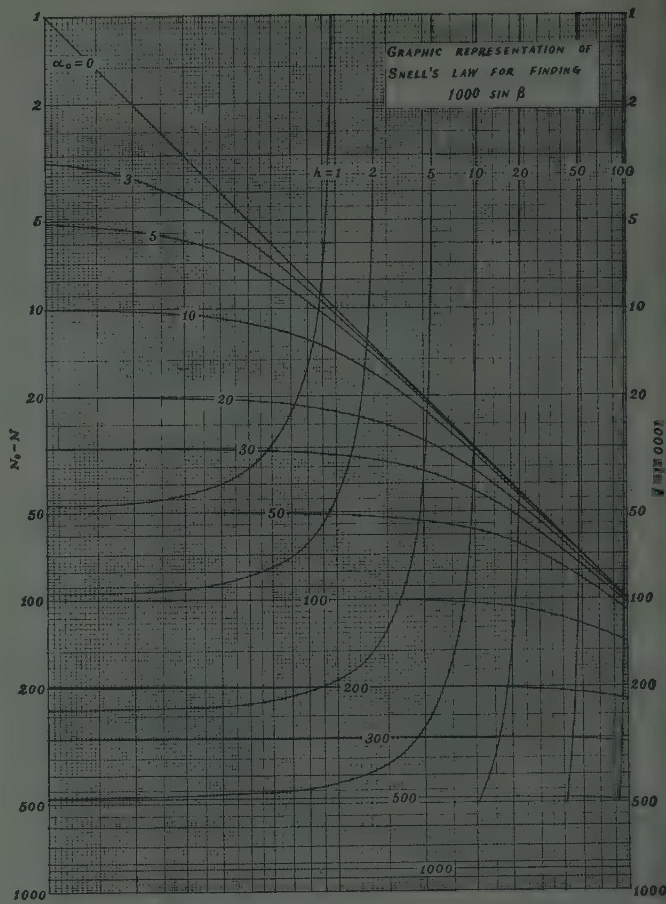

Fig. 4—Graphic representation of Snell's law for finding 1000 sin β.

$$\begin{aligned} \boldsymbol{F} &= e[\boldsymbol{E} + (\boldsymbol{V} \times \boldsymbol{B})] = m d\boldsymbol{V}/dt + m\nu \boldsymbol{V} \\ &= j\omega m \boldsymbol{V}(1 - j\nu/\omega) = j\omega m \boldsymbol{V}(1 - j\nu/\omega), \end{aligned} \tag{33}$$

where

$\boldsymbol{E}$ = the incident electric vector,
ν = angular collision frequency of electrons with air molecules,
ω = angular frequency of the incident signal,
$\boldsymbol{V}$ = velocity of the electron.

The phase term multiplying each term of (33) is

$$\exp\,[j\omega(t - \boldsymbol{n}\cdot\boldsymbol{R}/v)]$$

where

$\boldsymbol{n}$ = unit vector along direction of travel,
$\boldsymbol{R}$ = vector from the origin of the coordinate system to the point of interest,
v = phase velocity of the wave.

The formal solution of (33), in conjunction with Maxwell's field equations leads to the well known Appleton-Hartree equations which give the refractive index of the ionized medium. At very high radio frequencies the absorption is negligible since the ratio of collision fre-

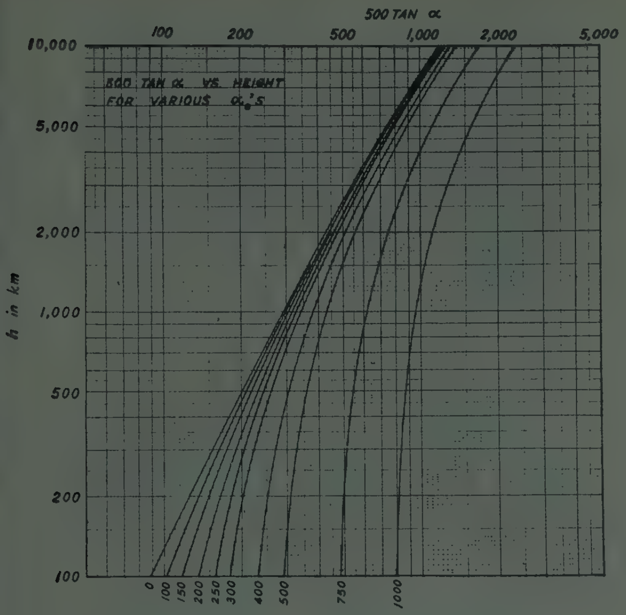

Fig. 5—500 tan α vs height for various angles of elevation in milliradians.

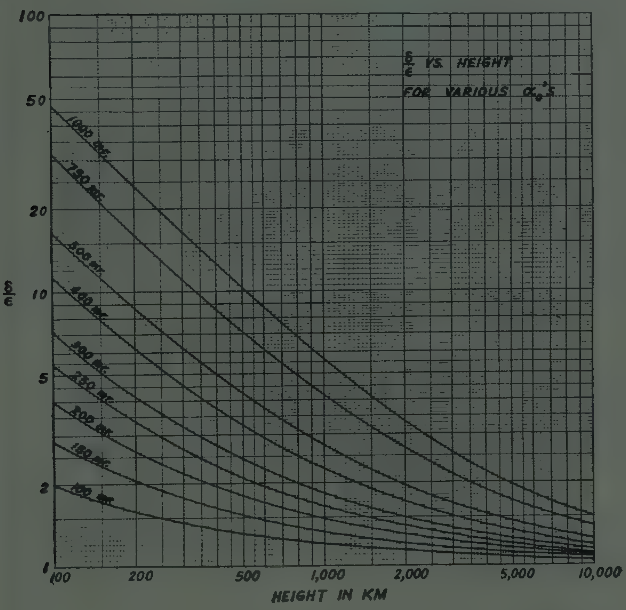

Fig. 6—δ/ϵ vs height for various angles of elevation in milliradians.

quency to operating frequency in the ionized region is extremely small. In addition, a number of simplifying assumptions are possible, and the resulting expression for the index of refraction is[7]

$$n^2 = (c/v)^2 = 1 - p^2 \pm p^2 g \cos\theta \tag{34}$$

[7] S. Weisbrod and J. L. Heritage, "Ionospheric Refraction and the Faraday Effect at Frequencies above 100 mc," ASTIA Document No. AD-138621, pp. 8–16; March, 1956.

where

p = ratio of plasma to operating frequency, $p = [(N_e e^2)/(m\epsilon_0\omega^2)]^{1/2}$; $p^2 \ll 1$,

N_e = electron density per cubic meter,

ϵ_0 = permittivity of free space = 8.854×10^{-12} farads/meter,

v = phase velocity of the wave,

c = velocity of light in vacuum,

g = ratio of gyro to operating frequency = $(eB/m\omega) \ll 1$,

θ = angle between the magnetic field and the direction of propagation. For values of θ very nearly 90°, (34) becomes inaccurate, but this is not a serious limitation since in most cases it does not apply.

It follows from (34) that, upon entering an ionized layer, the wave splits up into two components, each traveling with a different phase velocity. It can also be readily demonstrated that, if the coordinate system is chosen so that the magnetic field is along the z axis, and the direction of propagation is in the $x-z$ plane, the two components of the electric vector are:[7]

$$\begin{aligned} \boldsymbol{E}_{1,2} &= |E_y| (\pm j \cos\theta \boldsymbol{i} + \boldsymbol{j} + j \sin\theta \boldsymbol{k}) \\ &= |E_y| (\boldsymbol{j} \pm j\boldsymbol{t}) \end{aligned} \tag{35}$$

where $\boldsymbol{i}, \boldsymbol{j}, \boldsymbol{k}$ are unit vectors along x, y, z axis, and

$$\boldsymbol{t} = \boldsymbol{n} \times \boldsymbol{j} = -\cos\theta \boldsymbol{i} + \sin\theta \boldsymbol{k}.$$

It is seen from (35) that the two vectors represent two circularly polarized waves, each with an opposite sense of rotation. Since each travels with a slightly different velocity, the resultant of the two waves forms a plane wave whose plane of polarization rotates as it traverses through the ionized region. We shall now derive the equation of the combined wave

$$\boldsymbol{E}\text{ total} = \boldsymbol{E}_1 \exp[j\omega(t - r/v_1)] + \boldsymbol{E}_2 \exp[j\omega(t - r/v_2)] \tag{36}$$

where

$$r = x\sin\theta + z\cos\theta,$$

but from (34)

$$\begin{aligned} \frac{1}{v_{1,2}} &= \frac{\sqrt{1-p^2}}{c}\left(1 \pm \frac{p^2 g}{1-p^2}\cos\theta\right)^{1/2} \\ &\cong \frac{\sqrt{1-p^2}\,(1 \pm \frac{1}{2}p^2 g\cos\theta)}{c} \\ &= \frac{1}{v_0} \pm \frac{p^2 g\cos\theta}{2v_0} \cong \frac{1}{v_0} \pm \frac{p^2 g\cos\theta}{2c} \end{aligned} \tag{37}$$

where $v_0 = c/(1-p^2)^{1/2}$ = phase velocity in the absence of a magnetic field. Combining (35), (36), and (37) we obtain

$$E \text{ total} = 2|E_y| (\cos \beta r j + \sin \beta r t) \exp j\omega(t - r/v_0) \quad (38)$$

where

$$\beta = \frac{p^2 g}{2c} \omega \cos \theta.$$

Eq. (38) represents a plane wave whose plane of polarization rotates β radians per unit distance and whose phase velocity is v_0. In other words, while the earth's magnetic field has only a negligible effect on the phase velocity of the wave of very-high-frequency radio waves, it produces the so-called Faraday rotation and thus plays an important role in ionospheric propagation.

Ionospheric Refraction

In the preceding discussion it was shown that the index of refraction in the ionosphere, as far as the refractive bending is concerned, is given by

$$\begin{aligned} n &= [1 - (N_e e^2)/(m\epsilon_0 \omega^2)]^{1/2} = (1 - p^2)^{1/2} \\ &= 1 - \tfrac{1}{2}p^2 = 1 + N^i \times 10^{-6} \end{aligned} \quad (39)$$

where N^i, the ionospheric N, is defined in complete analogy to the tropospheric N.

Numerically N^i is given by

$$N^i = -4.03(N_e/f^2) \times 10^{-6}, \quad (40)$$

where f = signal frequency in megacycles, and N_e = electrons per cubic meter.

The two important differences between the ionospheric and the tropospheric N units are:

1) N^i is a negative quantity,
2) N^i is inversely proportional to the square of radio frequency.

At 100 mc the maximum value of N^i rarely exceeds -4000 units.

Ionospheric bending may be computed directly from (17). However, since the minimum angle of entrance into the ionospheric region is on the order of 160 milliradians, α and β are very nearly equal and only a small error will result if (16) is written as

$$\gamma_{jk} = \frac{|N_k^i| - |N_j^i|}{500(\tan \alpha_k + \tan \alpha_j)} \text{ milliradians.} \quad (41)$$

In Fig. 5, 500 tan α, corrected for nominal atmospheric refraction, is plotted vs height for various angles of elevation α_0. The correction for tropospheric refraction is less than two milliradians at very oblique incidence, and is based on the assumption that the surface value of index of refraction is 320 N units.

If $|N^i|$ is greater than a few thousand units, or if a high accuracy is required, α in (41) should be replaced with β. The relationship between the quantities is given by (21) and (40). If values of α are obtained from Fig. 5, which incorporates the tropospheric correction, (21) reduces to

$$\alpha - \beta = |N^i| \times 10^{-6} \cot \alpha. \quad (42)$$

Total bending γ is simply the sum of tropospheric and ionospheric contributions

$$\gamma_{\text{total}} = \gamma^t + \gamma^i \quad (43)$$

where superscript t and i refer to troposphere and ionosphere, respectively.

The ionospheric contribution to the refractive bending referred to the earth's center at a given height is, from (18) and (21),

$$\epsilon^i = \gamma^i - |N^i| \times 10^{-6} \cot \alpha. \quad (44)$$

Total ϵ is

$$\begin{aligned} \epsilon_{\text{total}} &= (\gamma^t - N_0 \times 10^{-6} \cot \alpha) \\ &\quad + (\gamma^i - |N^i| \times 10^{-6} \cot \alpha) = \epsilon^t + \epsilon^i. \end{aligned} \quad (45)$$

The elevation-angle error is obtained most conveniently from (23), or approximately from (25) and Fig. 5.

When γ and δ have been determined, the Doppler error due to refraction can be readily obtained from (28). At 100 mc, the maximum magnitude of Doppler error will be on the order of one per cent, and will approach zero at very great distances since γ and δ approach each other. The error will rapidly decrease for larger angles of elevation or higher frequencies.

In discussing the retardation effect of the ionosphere, one must remember that the ionosphere is a dispersive medium, and a distinction must be made between the group and phase velocities. For computing the refractive effects we used the phase velocity which exceeds velocity of light in free space, but, in considering the retardation, we must use the group velocity which represents the velocity with which energy propagates through the medium. The relation between the two is

$$c/v_p = v_g/c \quad (46)$$

and

$$\begin{aligned} c/v_g - 1 &= v_p/c - 1 = (1 - n^i)/n^i = -N^i \times 10^{-6} \\ &= |N^i| \times 10^{-6}. \end{aligned} \quad (47)$$

Comparison with (29) shows that the computing of ionospheric retardation (31) is perfectly valid, provided that the absolute value of N^i is used. As in the case of refractive computations, we can replace β with α without causing a serious error.

Thus, if h is in kilometers

$$\Delta r_{jk} = \frac{(|N_k^i| + |N_j^i|)(h_k - h_j)}{1000(\sin \alpha_k + \sin \alpha_j)} \text{ meters.} \quad (48)$$

In Fig. 7, 1000 sin α corrected for tropospheric refraction is plotted vs h for various α_0's. As before, the assumed value of N_0 was taken at 320 units. Since this correction is very small, the exact value of N_0 is unimportant.

The value of Δr_{jk} as given by (48) [or (31)] was compared with the exact solution of (30). It was found that for $\alpha_j = 150$ milliradians and layer thickness of 20, 50 and 100 kilometers, the values were 1.4, 3.9 and 7.2

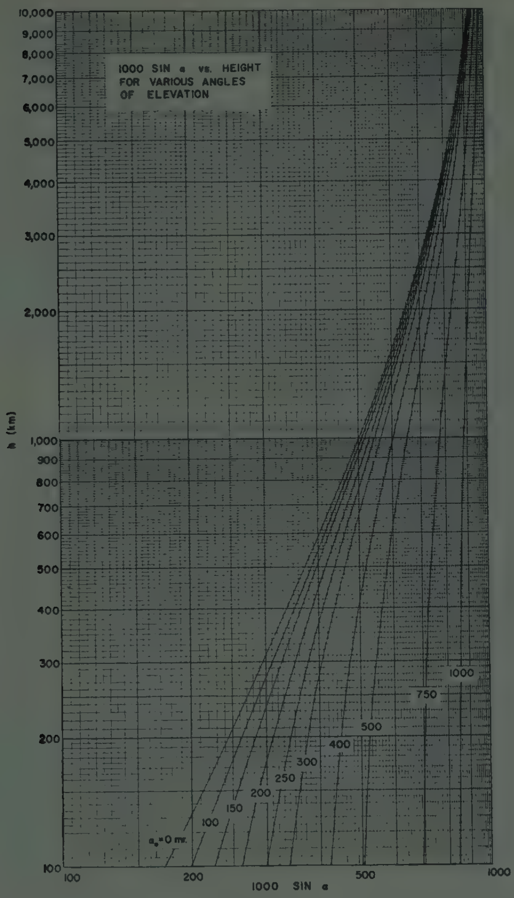

Fig. 7—1000 sin α vs height for various angles of elevation in milliradians.

per cent too high. With the angle of entrance of 200 milliradians, these errors dropped to 1.15, 2.7 and 4.7 per cent. From the above comparisons it is obvious that (48) is adequate for all practical applications.

One effect which is unique to ionospheric propagation is the Faraday rotation. From (38) this rotation amounts to $(p^2 g\omega/2c)\cos\theta$ radians per unit distance for a single passage through the layer. Since distances under consideration are small compared to earth's radius, the strength of the magnetic field, and hence g, the ratio of the gyro to operating frequency, is very nearly constant. Also, the rate of change of electron density per unit distance of the ray path is small compared with the wavelength of the signals. Thus we can state that the number of rotations of the plane of polarization for a double passage through the layer bounded by heights ρ_k and ρ_j is

$$\Omega = \int_{\rho_j}^{\rho_k} (\rho^2 g\omega/2nc)\cos\theta dr = \lambda_g^{-1}\int_{\rho_j}^{\rho_k} \rho^2 \cos\theta dr \quad (49)$$

where

$\lambda_g = c/f_g =$ gyro wavelength inside the layer
$= 109/B$ meters

$B =$ intensity of the terrestrial field in gauss.

At ionospheric heights typical values of λ_g are on the order of 250 meters.

From (2) and (39) we have

$$dr = Kd\gamma = \csc\beta d\rho$$

$$p^2 = 2|N^i| \times 10^{-6}.$$

Also, in any one lamination which does not exceed fifty or a hundred kilometers in thickness (which certainly represents the practical case), λ_g and $\cos\theta$ are nearly constant and (49) may be written as

$$\Omega_{jk} = 2\lambda_g^{-1}\cos\theta \int_{\rho_j}^{\rho_k} |N^i| \times 10^{-6}\csc\beta d\rho \quad (50)$$

which, compared with (30), yields

$$\Omega_{jk} = 2\lambda_g^{-1}\cos\theta\Delta r_{jk} \quad (51)$$

where $\cos\theta_{jk} =$ value of $\cos\theta$ in the middle of the layer.

From (51) it appears that ionospheric retardation is very closely related to the Faraday rotation. In most practical applications λ_g and $\cos\theta$ are not rapidly varying functions of the ray path. If we use a constant value for $\cos\theta$ equal to that encountered at the midpoint of the path, or, in the case of very long paths, in the region of maximum electron density, no serious error will result; and, according to (51) Faraday rotation will be directly proportional to the total ionospheric retardation. The constant of proportionality $2\lambda_g^{-1}\cos\theta$ is, of course, a function of geometric and geomagnetic factors of the transmission path.

Discussion of Relativity and Space Travel

There appear below four letters commenting on a recent PROCEEDINGS *paper. The author's reply to all four correspondents follows the fourth letter.—The Editor.*

Comment on Relativity and Space Travel*

Pierce's recent article on relativity[1] gave a very good summary of current opinions, and is to be commended for being free of the sensationalism with which semipopular articles (and, alas, even textbook discussions) only too often abound. It is a pity that the comments under "Scanning the Issue" chose to go a little further, in speaking of "leaving his familiar Newtonian world. . . ." Just how "unfamiliar" will the "new, relativistic, world" be?

At present, it is barely possible to attain escape velocity, about 11 km/sec. Suppose that, in the not-too-distant future, it becomes possible to attain velocities ten times that figure. The earth's velocity in its orbital motion, about 30 km/sec., might be added to that, giving about 150 km/sec. For the sake of round figures, double that, to suppose that velocities around 300 km/sec might be forseeable. This figure is just 10^{-3} times the speed of light. In the relativistic equations, the factors supposed to be involved with the peculiar effects are usually of the form $(1-V^2/C^2)^{1/2}$. Thus, since $V/C = 10^{-3}$, it appears that the space traveler might find his "new world" "unfamiliar" to the extent of about one part per million. So it would take a rather precise experiment to see that the "new world" was "unfamiliar" at all.

This communication, however, is not intended just to raise a quibble. There are two matters of some importance which deserve comment.

In the first place, the article brings up again the proposal of launching a very accurate oscillator in a satellite so that its behavior may test the theory of relativity. The writer maintains that the experiment would test nothing except the behavior of an oscillator of such-and-such a design traveling in a satellite under such-and-such conditions. How many alleged "crucial experiments" have been performed in the past, and can any of them "prove" any theory, in the sense of showing that the theory in question is not only *sufficient* but also *necessary*, to explain the results? It is generally (although, perhaps, not very openly) admitted now that the "crucial experiments" which were once supposed to prove the theory of relativity did not accomplish that aim.[2] On the basis of Ritz's electrodynamics,[3] *e.g.*, the outcome of the Michelson-Morley[4] and Trouton-Noble[5] experiments was a foregone conclusion. The advance in the perihelion of Mercury could be explained in various ways,[2] and the other experiments, such as the "bending of light rays" near the sun do not agree at all well with the theoretical value.[2,6] Perhaps, then, some rather critical consideration is indicated before deciding on a great expense of money and effort to launch the oscillator in the satellite.

The second point which deserves to be made is this. Some rather pointed arguments against certain of the conclusions of relativity, and even more against some of the arguments offered in support of those conclusions, have been advanced, and it seems only right that the readers should at least have heard of them. Brown[2,7,8] has given some very interesting discussions of these matters, Moon and Spencer[9] have carried out some interesting analyses bearing on the subject, and, last but by no means least, O'Rahilly's book[10] offers a stimulating and critical investigation of some of these points.

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* Received by the IRE, June 29, 1959.

[1] J. R. Pierce, "Relativity and space travel," PROC. IRE, vol. 47, pp. 1053–1061; June, 1959.

[2] G. B. Brown, "Have we abandoned the physical theory of nature?," *Science Progress*, vol. 44, pp. 619–634; October, 1956.

[3] Ritz's original work is not very accessible nowadays. A discussion may be found in chapter 11 of O'Rahilly's book (see footnote 10).

[4] G. Joos, "Theoretical Physics," Blackie and Son Ltd., London, Eng., 1st ed., p. 226; 1934.

[5] *Ibid.*, p. 447.

[6] E. Finlay-Freundlich, "Du déplacement general vers la rouge des raies du specre solaire," *Ann. Phys.*, ser. 13, vol. 2, pp. 765–777; November–December, 1957.

[7] G. B. Brown, "A theory of action—at-a-distance," *Proc. Phys. Soc. B*, vol. 68, pp. 672–678; September, 1955.

[8] G. B. Brown, "The unification of macroscopic physics," *Science Progress*, vol. 46, pp. 15–29; January, 1959.

[9] P. Moon and D. E. Spencer, "Interpretation of the ampere experiment," *J. Franklin Inst.*, vol. 257, pp. 203–220; March, 1954; "The coulomb force and the ampere force," pp. 305–315; April, 1954; and "A new electrodynamics," pp. 369–382; May, 1954.

[10] A. O'Rahilly, "Electromagnetics," Longmans, Green, and Co., London, Eng.; 1938.

The Clock Paradox[11]

In a recent paper[1] Pierce discussed the clock paradox in the special theory of relativity. According to this paradox, one of two identical twins goes off in a starship at 99.5 per cent of the speed of light. As observed from earth, his clock runs only 1/10 of normal speed. Ten years after takeoff he lands back on earth. The "traveling" twin has aged during this time by only 1 year while his "stationary" brother is 10 years older than when the ship started.

The clock paradox controversy is almost as old as the special theory of relativity itself. On one side there are the authors who state that the clock paradox is a *physical reality*.[12–17] On the other side there are the authors who cannot accept it as a physical reality and try to explain the paradox by different theories.[18–24] One author, who will remain nameless, even suggested that we could never reach any great velocities at all, so the clock paradox does not really exist. To his credit I should say that his paper was published before the satellites started to rotate around the earth.

In his original paper[25,26] Einstein based his special theory of relativity on two postulates:

1) If a system of coordinates K is chosen so that, in relation to it, physical laws hold good in their simplest form, the *same* laws also hold good in relation to any other system of coordinates K' moving in a *uniform* translation relative to K.

2) The light is always propagated in empty space with a definite velocity c, which is independent of the state of motion of the emitting body.

We have to realize in the clock paradox that the "traveling" twin, in order to reach velocities close to the velocity of light, should *accelerate* and *decelerate* his space vehicle before he will come back to the exact same position as his brother. As we see above, *no* discussion of the effects of acceleration is possible at all in the special theory of relativity.

In his paper on the general theory of relativity[26,27] Einstein has discussed gravitation fields and acceleration. However, this part of his theory is far from being perfect and has been checked with any real accuracy in only *two* observations. Extensive discussions on the general theory of relativity and *other* possible theories of gravitation may be found in several places.[28]

The author of this letter and quite a few others find it impossible to believe (unless a definite experiment proves otherwise!) in the physical reality of the clock paradox and in two twins where one is younger than

[11] Received by the IRE, June 29, 1959.

[12] H. Dingle, *Proc. Phys. Soc. (London) A*, vol. 69, p. 925; 1956.

[13] E. M. McMillan, "The clock paradox and space travel," *Science*, vol. 126, pp. 381–384; August 30, 1957. See references cited therein.

[14] H. Dingle, *Science*, vol. 127, p. 158, 1958.

[15] E. M. McMillan, *Science*, vol. 127, p. 160; 1958.

[16] R. M. Frye and V. M. Brigham, *Amer. J. Phys.*, vol. 25, p. 553; 1957.

[17] R. H. Romer, *Amer. J. Phys.*, vol. 27, p. 131; 1959.

[18] C. Moller, "The Theory of Relativity," Oxford University Press, London, Eng., p. 258; 1952.

[19] E. G. Cullwick, "Electromagnetism and Relativity," Longmans, London, Eng., p. 70; 1957.

[20] R. C. Tolman, "Relativity, Thermodynamics, and Cosmology," Oxford University Press, London, Eng., p. 166; 1934.

[21] J. W. Campbell, *Phil. Mag.*, vol. 15, p. 48; 1933.

[22] W. Campbell, *Phil. Mag.*, vol. 16, p. 529; 1933.

[23] E. L. Hill, *Phys. Rev.*, vol. 72, p. 236; 1947.

[24] C. B. Leffert and T. M. Donahue, *Amer. J. Phys.*, vol. 26, p. 8, 1958.

[25] A. Einstein, "Zur Elektrodynamik bewegter Korper (On the electrodynamics of moving bodies)," *Ann. der Phys.*, vol. 17; 1905.

[26] H. A. Lorentz, A. Einstein, H. Minkowski, and H. Weyl, "The Principle of Relativity," Methuen, London, Eng.; 1923.

[27] A. Einstein, "Die Grundlage der allgemeinen Relativitatstheorie (The foundation of the general theory of relativity)," *Ann. der Phys.*, vol. 49, 1916.

[28] *Revs. Modern Phys.*, vol. 29, pp. 325–546, July 3, 1957 includes quite a few references.

the other. The explanation of the clock paradox probably lies somewhere in the acceleration and the deceleration of one system compared to the other. Therefore the author suggests the following *postulate:*

Two identical material bodies at the *same* position at the *same* time t_0 and at rest with respect to the *same* coordinate system will remain identical at any future time t_1 under the above conditions, regardless of their relative movements between the times t_0 and t_1. This basic postulate could be made into an additional check[28] on any general theory of relativity.

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Relativity and Space Travel[29]

Pierce[1] has given his solution of the famous "clock paradox," and finds that the crew on a starship age less rapidly than those left behind on earth. He does mention the fact that there are those who do not agree with this. This note is written to present the opposing point of view.

Let us start with the postulates of the special theory.

Postulate I—The laws of electrodynamics (including, of course, the propagation of light with the velocity c in free space), as well as the laws of mechanics, are the same in all inertial frames.

Postulate II—It is impossible to devise an experiment defining a state of absolute motion, or to determine for any physical phenomena a preferred inertial frame having special properties.

In a general sense, Postulate II is all that is required to show that Pierce's solution is incorrect. Since, in common with most modern writers on this subject, he has ruled out any effect of acceleration on clocks, his problem becomes that of two inertial frames with uniform relative velocity. Then the measurement of the elapsed time between the two events, the departure of the starship from earth and its return thereto, must be the same on the earth's clock as well as the starship's, since they have measured the same events, at the same place, and in a state of relative rest. Otherwise Postulate II is violated. A solution giving different elapsed times is impossible, or, to quote Pierce, "we simply can't have such a thing and relativity too; one or the other will have to go."

This argument is conclusive, but probably not very satisfying. The trouble is that one of the logical consequences of Postulates I and II can be stated loosely as, "moving clocks go more slowly than stationary ones." As a result, one intuitively, but wrongly, thinks that the moving clock must show a shorter elapsed time after its return. This is what leads to the famous paradox, since the relativist can draw no distinction between earth and starship, and has both clocks running slow, depending on the viewing point. He infers that the elapsed times are impossible—both observers cannot be right, and hence the paradox.

Actually, in making this inference, both observers would be equally wrong. If they reasoned accurately from Postulates I and II, each would be prepared to find the other's clock agreeing with his, after coming to rest for a comparison. Hence, the paradox does not exist—it is merely wrong reasoning that makes it appear to be present.

Let us examine this further. Postulates I and II have certain logical consequences, the mathematical expression of which is the Lorentz transformation. If A and B are two inertial frames moving with uniform relative velocity, three effects occur which are of particular interest. If A looks at B's measuring rods, he finds them shorter than his own, in the direction of motion. If B has a system of clocks spaced along his direction of motion, and nicely synchronized according to B, A finds that they are not synchronized. Finally, A observes that B's measurement of the time interval between two events occurring at the same place in A's frame does not agree with A's measurement, and, in fact, indicates a shorter time than A measures. From this, A infers that B's clocks must be running at a slower rate than his own.

An essential part of special relativity is that the effects mentioned in the preceding paragraph are completely reciprocal and symmetrical. That is, if B is substituted for A, and A for B, in the paragraph, it will still be true. Both observers are right in their observations.

Having concluded that the clocks on both the earth and starship will show exactly the same elapsed time for the round trip, what will this time be? If the observer on the earth knows the velocity of the spaceship relative to him, and the distance covered in the round trip, he can calculate the total elapsed time, and this is exactly what his clock will show him. The same is true for the observer in the starship, and his clock will show the same time.

If the two observers measure the rate of each other's clocks, each will find the other's going slower than his own, and both will be right. If they infer from this, however, that the other man's clock will show an elapsed time less than his own, they will be wrong.

Further elaboration of this theme is found in Dingle.[30] A detailed solution of the earth and starship problem is given by Cullwick.[31]

Referring specifically to Pierce's argument, this is a mathematically dressed up version of one already put forward by Darwin.[32] This was criticized by Dingle,[33] who pointed out the error, namely, that in a problem based on the postulates of the special theory, you cannot introduce a preferred frame of reference. In essence, this is what both Darwin and Pierce do when they say that things look different to the starship's observer because he is the one who pushes the button that fires the rockets.

In some ways the clock paradox is a trivial problem. McMillan,[13] who makes the same error of the preferred frame in his treatment, has calculated the energy required to drive a practical starship to the velocities required to gain some appreciable age advantage. This turns out to be some orders of magnitude greater than any energy source in the foreseeable future.

The main reason for still belaboring the clock paradox is that it is a fallacy based on erroneous reasoning, and can do great harm in confusing future students of relativity. Further, when asymmetrical aging is seriously presented to Congressional committees as another reason for exploration of space, it is time to call a halt, before our scientific advisers are embarrassed.

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[29] Received by the IRE, July 6, 1959.

[30] H. Dingle, "What does relativity mean?," *Bull. Inst. Phys.*, vol. 7, pp. 314–323; December, 1956.
[31] Cullwick, *op. cit.*, footnote 19, pp. 70–76.
[32] C. G. Darwin, "The clock paradox in relativity," *Nature*, vol. 180, pp. 976–977; November 9, 1957.
[33] H. Dingle, "The clock paradox in relativity," *Nature*, vol. 180, pp. 1275–1276; December 7, 1957.

The Clock Paradox[34]

I was sorry to see a further confusion of the clock paradox published in the Proceedings.[1] It is hoped that the following explanation will settle this controversy once and for all.

First let me point out the fallacy in Pierce's "resolution" of the paradox. His argument is correct up to the sentence:[35] "But, when we reach * we change our motion . . ." which leads to the erroneous (49). The statement here should be: "But, when we reach * the earth appears to turn around at a distance LS." The derivation then proceeds precisely as for (45), except that the apparent distance is now LS instead of L; then (49) becomes:

$$N_e = 2Lfv^{-1}[1 - (v/c)^2] = SN_s.$$

Thus when the earth-bound twin "comes back" he will have aged *less* than the ship-bound twin by the shrinking factor $S = [1-(v/c)^2]^{1/2}$. To use the figures in the article, the earth twin seems to have aged 1/10 year while the starship twin has aged 1 year;[36] from the earth twin's point of view the traveler has still aged 1 year, but he himself has aged 10 years. This is the paradox!

The only way to clear up the paradox is to take account of the acceleration required to reach the velocity v and the deceleration needed to stop before turning around. The earth is approximately an inertial system,

[34] Received by the IRE, June 15, 1959.
[35] Pierce, *op. cit.*, p. 1058, column 2, line 4.
[36] The statement "Should we say . . . ?" in Pierce's article, *ibid.*, p. 1057, column 1, line 6 from bottom, does not give a valid comparison; the apparent distance has shrunk to 1/10 so the times should be smaller in the same ratio.

while the spaceship must be treated as an accelerated or noninertial system; this destroys the symmetry which gives rise to the paradox. Suppose, for simplicity, that the spaceship goes half the distance out at an acceleration g, goes the remaining half while decelerating at the same rate, and returns in the same manner. These accelerations are taken to be the *subjective* accelerations of the traveler, that is, with respect to an inertial frame in which the ship is instantaneously at rest. From the point of view of an observer on earth the ship's acceleration is:

$$du/dt = [1 - (u/c)^2]^{3/2}g,$$

where u is the velocity of the ship in the earth's reference frame and t is earth time.[37] Hence:

$$t_e = 4\int_0^v dt = 4\int_0^v g^{-1}[1 - (u/c)^2]^{-3/2}du$$

$$= 4vg^{-1}[1 - (v/c)^2]^{-1/2},$$

where v is the final velocity attained.[38] On the other hand, increments of time on the ship are related to increments of time on earth by:

$$dt' = [1 - (u/c)^2]^{1/2}dt,$$

so that:

$$t_s = 4\int_0^v dt' = 4\int_0^v g^{-1}[1 - (u/c)^2]^{-1}du$$

$$= 2cg^{-1}\ln\frac{1 + (v/c)}{1 - (v/c)},$$

which is always less than the time t_e because of the shrinking factor. For the distance (one-way) one has the relation:

$$L = 2\int_0^v u\,dt = 2\int_0^v g^{-1}[1 - (u/c)^2]^{-3/2}u\,du$$

$$= 2c^2g^{-1}\{[1 - (v/c)^2]^{-1/2} - 1\}.$$

For example, if $v=0.995c$ and $g=9.88$ m/sec^2 (normal gravity), $t_e=64$ years, $t_s=19.23$ years, and $L=29.9$ light-years.

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[37] A derivation of this relation may be found in the book by I. Landau and E. Lifshitz, "The Classical Theory of Fields," Addison-Wesley Press, Inc., Cambridge, Mass., p. 23; 1951.

[38] The factor 4 arises from the four legs of the trip each of which takes the same time.

The Clock Paradox[39]

There is some overlap in the comments of various correspondents on my paper,[1] and perhaps it will be adequate if I reply in a rather general way.

Special relativity asserts that the same physical laws apply in all unaccelerated coordinate systems regardless of the relative velocities of the different systems. Nowhere in my paper would the addition of a constant velocity to a coordinate system have changed any of the conclusions. In any particular unaccelerated coordinate system, one can make valid calculations of acceleration, as Gadsden does.

Special relativity does *not* say that events in a coordinate system tied to an accelerated object must or can be computed in exactly the same way as events in an unaccelerated coordinate system. However, a false assumption to this effect repeatedly creeps into discussions of the "clock paradox."

The fact is that on reaching the star, when the ship (or the rest of the universe) turns around, the frequency received by the ship from the earth changes, and it does not change again during the "return trip." This fact we can express from more than one point of view, but it is always different from the case of the radiation reaching the earth from the ship, which does *not*, in anyone's book, change frequency when the ship is in the vicinity of * ("turning around").

If we wish to allow the space pilot to insist that ship coordinates are as good and as universal as any others, then something beyond special relativity is needed. We must note that if the spaceship observer insists that he remain stationary at all times, then he must assume a gravitational field which acts *not only* on the earth, but on the *intervening radiation as well.* This I point out in my paper[1] in the second column of page 1059, just prior to Section VI. This field would presumably change the frequency of the radiation reaching him immediately following "turnaround."

We must also note that while there are many experimental verifications of special relativity, alleged verifications of general relativity are widely regarded as inconclusive.

The laws of motion of special relativity are attested by the fact that such devices as the billion-volt Stanford electron accelerator work as planned, and by many atomic phenomena. The time dilatation is attested by the lengthened life of fast mesons and by Ives' experiments which showed a frequency reduction in the radiation from rapidly moving molecules.[40] The tests of general relativity (the red shift of light from the sun and stars, the advance in the perihelion of Mercury, and the deflection of light in a gravitational field) can be regarded as inconclusive or at least as not absolutely conclusive.

Personally, I find it hard not to believe in the gravitational frequency shift described in Section VI of my paper, because of the simple (though perhaps fallible) arguments which lead to it. However, I do look forward to the results of satellite clock experiments.

Of course I have no direct experience with human travel at velocities near that of light. I cannot assert that I have seen twin B age one year while twin A aged 10 years. However, a consistent interpretation of various experimental results leads me to believe that this would happen. What am I to say, however, if someone states that he finds this impossible to believe, even in the absence of experimental contradiction? I can only assume that he has some firm and final direct insight into the laws of nature which has been denied to me.

With regard to the comments concerning the words near the bottom of column 1, page 1057, I did not propose to get the right answer at that point, and as I had not brought distance in, I could scarcely refer to it.

The various correspondents cite a number of references, many of them unfamiliar to me. I will note that Coupling[41] pointed out the unconscionable energy required to approach the speed of light two years before McMillan did.

A truly excellent paper[42] treating the "clock paradox" in special relativity in terms of proper time has come to my attention since my paper was published.

I wish to thank R. S. Fuller for pointing out that in my paper, lines 10 and 11, page 1053, column 2, should read "traveling ship R, and the other from the nose of ship R to the tail of ship L," and in the last term of (24), v_x should be replaced by v_y in the numerator.

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[39] Received by the IRE, July 16, 1959.

[40] H. E. Ives and G. R. Stilwell, "Experimental study of the rate of a moving clock," *J. Opt. Soc. Amer.*, vol. 28, pp. 215–226, July, 1938; Part II, vol. 31, pp. 369–374, May, 1941.

[41] J. J. Coupling, "On atomic jets," *Astounding Science Fiction*, vol. 54, pp. 115–127; January, 1955.

[42] A. Schild, "The clock paradox in relativity theory," *Amer. Math. Monthly*, vol. 66, pp. 1–18; January, 1959.

Correspondence

Hall Effect in High Electric Fields*

In a recent communication[1] Gibbons has pointed out some advantages which one has in using the Hall effect in high electric fields, where the drift velocity becomes almost independent of the applied electric field. He goes on to compare the materials germanium, silicon and indium antimonide used in this way, and, on the basis of the curves shown in his Fig. 2, recommends silicon as the material with the largest drift velocity, above fields of 10^4 v/cm.

It is the purpose of this note to point out that some of the curves shown in Fig. 2 are not in agreement with the most recent published data. Table I summarizes this situation. In the case of indium antimonide at room temperature, Prior's observations show that the drift velocity is still rising at least as fast as the electric field (no sign of "saturation") at 800 v/cm; if it "saturates" it should then do so at some value well above the velocity of 3.4×10^7 cm/sec estimated at this field strength. In the observations at lower temperature,[5] the drift velocity was obtained from Hall effect measurements. At 1050 gauss, this velocity was 5.4×10^7 cm/sec (and still rising) at 350 v/cm. It was found that the drift velocity showed "saturation" in *larger* magnetic fields of 3500 and 7000 gauss, for electric fields of 300 and 150 v/cm, respectively.

TABLE I

Semi-conductor	"Saturation" drift velocity at room temperature (cm/sec)	"Saturation" drift velocity at 77° K (cm/sec)
Ge[2,3]	7×10^6	9×10^6
Si[3]	8.2×10^6	—
InSb[4,5]	$>3.4\times10^7$	$>5.4\times10^7$

Using these data, one would conclude that the semiconductor indium antimonide offers appreciable advantages over silicon and germanium, both in the output voltage (proportional to the drift velocity) and in the possible applicability at much lower electric fields of the "saturated" condition.

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* Received by the IRE, February 18, 1959.

[1] J. F. Gibbons, "Hall effect in high electric fields," Proc. IRE, vol. 47, p. 102; January, 1959.
[2] J. B. Gunn, "The field-dependence of electron mobility in germanium," *J. Electronics*, vol. 2, pp. 87–94; July, 1956.
[3] E. J. Ryder, "Mobility of holes and electrons in high electron fields," *Phys. Rev.*, vol. 90, pp. 766–769; June 1, 1953.
[4] A. C. Prior, "Avalanche multiplication and electron mobility in indium antimonide at high electric fields," *J. Electronics and Control*, vol. 4, pp. 165–169; February, 1958.
[5] M. C. Steele and M. Glicksman, "High electric field effects in *n*-indium antimonide," *J. Phys. Chem. Solids*, vol. 8, pp. 242–244; January, 1959. For earlier data, see *Phys. Rev.*, vol. 110, pp. 1204–1205; June 1, 1958.

The Manley-Rowe Relations*

Parametric amplifiers can be regarded as linear circuits, in which some element is varied periodically by external means, or as nonlinear circuits, in which the action of the nonlinear element is not an explicit function of time but only a function of the instantaneous value of the voltage (or current) affecting it. In the second interpretation, the pump is a secondary signal source and the parametric amplifier mixes the pump-wave with the signal.

For such nonlinear circuits, when the nonlinear element is reactive, Manley and Rowe[1] have derived two general equations:

$$\sum_{n,m}\frac{nW_{n,m}}{(nf_0+mf_1)}=0 \qquad (1)$$

$$\sum_{n,m}\frac{mW_{n,m}}{(nf_0+mf_1)}=0 \qquad (2)$$

where $W_{n,m}$ is the average energy of the product-harmonic of frequency nf_0+mf_1 and f_0 and f_1 are the frequencies of the two mixing signals (the two fundamental frequencies). The two equations are energy relations for a completely closed system and there cannot be any exchange of energy with an external source. The system must include all signal sources and loads.

Manley and Rowe derived the equations from the properties of Fourier series in a two-dimensional space. One can also derive them from the conservation of energy.

The conservation of energy yields:

$$\sum_{n,m} W_{n,m}=0. \qquad (3)$$

Eq. (3) is identical to:

$$W_{00}+f_0\sum_{n,m}\frac{nW_{n,m}}{(nf_0+mf_1)}+f_1\sum_{n,m}\frac{mW_{n,m}}{(nf_0+mf_1)}=0. \qquad (4)$$

The dc term is necessary in order not to multiply and divide by zero.

One should note that:

$$\frac{W_{n,m}}{nf_0+mf_1} \qquad (5)$$

is the average work exchanged by a given product-harmonic within one of its periods.

To deduce the Manley-Rowe equations from (4), it is only necessary to assume the dc energy zero and to prove that the work of each product harmonic averaged over its own period is independent of the values of the fundamental frequencies. To prove that the work per period for each product harmonic is independent of the fundamental frequencies, one has only to find two circuits such that the work per period of the corresponding product harmonics in both circuits is the same, although the fundamental frequencies are chosen different. Such a proof has been given elsewhere.[2] The proof is, of course, only valid when all nonlinear elements are reactive.

The derivation can be extended to the case when more than two fundamental frequencies exist. One obtains:

$$\sum_\nu f_\nu \sum_{n_0,n_1,\cdots,n_\nu,\cdots}\frac{n_\nu W_{n_0,n_1,\cdots,n_\nu,\cdots}}{n_0f_0+n_1f_1+\cdots+n_\nu f_\nu+\cdots}=-W_{0,0} \qquad (6)$$

or, when the dc energy is zero:

$$\sum_{n_0,n_1,\cdots,n_\nu,\cdots} n_\nu\frac{W_{n_0,n_1,\cdots,n_\nu,\cdots}}{n_0f_0+n_1f_1+\cdots+n_\nu f_\nu+\cdots}=0. \qquad (7)$$

The sign of the average energy exchanged by each product-harmonic must be considered. Energy can be generated by a source or absorbed by a load. Because there are only two possibilities, it does not matter which sign is chosen for the generation or correspondingly for the absorption.

Let one assume generation positive, absorbtion negative. Eq. (4) for a common linear amplifier, yields:

$$W_{00}+W_{1,0}=0. \qquad (8)$$

The dc energy is generated and positive, the ac energy is absorbed and negative. The sum of the two is naturally zero. In the case of an oscillator, $W_{1,0}$ is purely absorbed. In the case of an amplifier, $W_{1,0}$ is made of the sum of the negative ac energy absorbed by the load and the positive ac energy generated by the signal generator. There is not any difference in the form of (8) for the oscillator and for the amplifier. Eq. (8) does not tell *per se* if a device is an oscillator or an amplifier, is stable or unstable. The dc energy is also a sum, the sum of the positive dc energy supplied by the power supplies and the negative dc energy absorbed by the resistances.

The same fundamental reasoning applies to the Manley-Rowe relations in the case of the parametric amplifier with idler and the up-converter.

For the parametric amplifier:

$$\frac{W_{1,0}}{f_0}-\frac{W_{-1,1}}{f_1-f_0}-0 \qquad (9)$$

$$\frac{W_{0,1}}{f_1}+\frac{W_{-1,1}}{f_1-f_0}=0. \qquad (10)$$

For f_1 larger than f_0, signal power $W_{1,0}$ and idler power $W_{-1,1}$ are negative. The pump power $W_{0,1}$ is positive. The signal power is the sum of the signal power absorbed in the load and of the signal power generated by the signal generator. The idler power is only absorbed power. The two equations prove that not only signal power but also idler

* Received by the IRE, March 2, 1959.

[1] J. M. Manley and H. E. Rowe, "Some general properties of nonlinear elements—part I," Proc. IRE, vol. 44, pp. 904–913; July, 1956.

[2] P. A. Clavier, "Parametric Amplifiers," published notes on lectures given at Cornell University, Ithaca, N. Y.; October, 1958.

power must be absorbed by adequate loads. The sign of $W_{1,0}$ is not proof *per se* of the instability of most parametric amplifiers. Indeed, electronic parametric amplifiers are stable.

In the case of the up-converter, the Manley-Rowe equations yield:

$$\frac{W_{1,0}}{f_0} + \frac{W_{1,1}}{f_1 + f_0} = 0 \qquad (11)$$

$$\frac{W_{0,1}}{f_1} + \frac{W_{1,1}}{f_1 + f_0} = 0. \qquad (12)$$

The output energy $W_{1,1}$ is absorbed by the load. Both signal energy $W_{1,0}$ and pump energy $W_{0,1}$ are generated by power sources. The sign of $W_{1,0}$ tells that the output is at a different frequency from the input. It also tells that an input signal generator is necessary. Eqs. (11) and (12) are proof *per se* of the stability of the up-converter.

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Short-Time Stability of a Quartz-Crystal Oscillator as Measured with an Ammonia Maser*

There are many applications, such as that required with atomic standards, where the very short time (second-to-second) stability of a quartz oscillator is important. Work at the National Bureau of Standards Boulder Laboratories on a high-precision oscillator, operated with the quartz crystal immersed in liquid helium, gave the results shown in Fig. 2. This may be compared with the short-time stability (Fig. 1) of another quartz oscillator with the crystal at about 40°C.

Temperature variations of the quartz crystal immersed in the liquid helium are reduced by controlling the pressure of the helium gas above the liquid. Apparently—compare Figs. 2 and 3—the regulator is adversely affecting the short-time stability of the oscillator. The pressure regulator, however, does provide satisfactory long-time stability.

About one hour trace was taken like that of Fig. 2, and about four hours like that of Fig. 3. The results were very consistent. The first run was made with the pressure regulator in operation for a period of over two hours and showed a drift of less than ~2 parts in 10^{11}. The following day, a trace was made without the pressure regulator. After about one hour of this recording, the pressure regulator was activated and the transition from the stability illustrated by Fig. 2 to that in Fig. 3 was observed.

The larger frequency fluctuations when the pressure regulator is used may be attributed to either the temperature change associated with pressure fluctuations or to

* Received by the IRE, April 9, 1959.

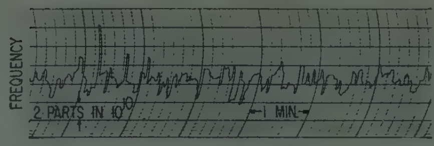

Fig. 1—Oscillator vs maser (approx. 40°C).

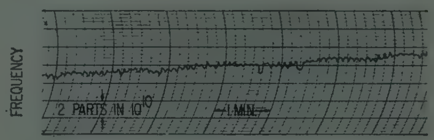

Fig. 2—Helium oscillator vs maser (no pressure control).

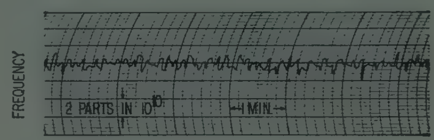

Fig. 3—Helium oscillator vs maser (pressure control).

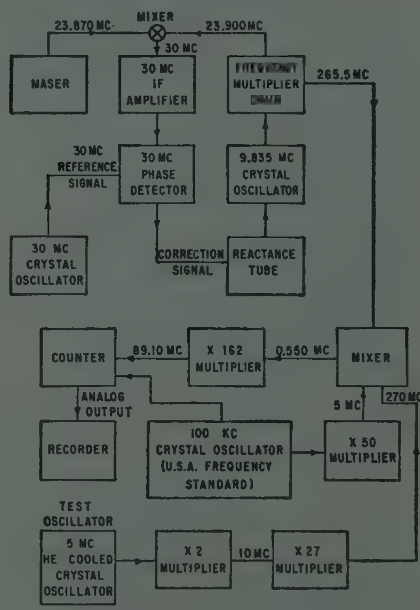

Fig. 4—Maser stabilized frequency-multiplier chain (all frequencies are nominal).

mechanical vibrations introduced by the regulator—crystals at very low temperatures are rather microphonic.

The quartz crystal was enclosed in an evacuated glass bulb and this was placed inside a brass cylinder. Liquid helium was in direct contact with the outside of the cylinder. A double dewar was used, with liquid nitrogen in the outer jacket and the helium in the inner container. In this system the pressure was regulated at about 650 mm of mercury.

The scheme used in comparing the helium-cooled oscillator with a maser-stabilized multiplier chain is shown in Fig. 4. The traces, of which Figs. 2 and 3 are samples, were derived from the analog output of the counter. The counter was set to count for one second and display for one second. Fluctuations at shorter time intervals—to 0.001 second[1]—could be observed with this maser apparatus with a somewhat different scheme of comparison. The minimum time interval in the above experiment was limited to one second by the electronic counter.

The authors wish to acknowledge the contribution of Dr. R. C. Mockler, who supervised the development of the maser, and also the helpful assistance of P. A. Simpson and J. B. Milton, who were responsible for the cryostat development and the construction and operation of the oscillator.

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[1] 0.001 second is the time constant of the maser servo-system.

Phase Considerations in Degenerate Parametric Amplifier Circuits*

A previous paper[1] has given an expression for the negative resistance introduced into the signaling circuit of a degenerate parametric amplifier employing a quadratic nonlinearity of the magnetic type. It is the purpose of my paper to examine this resistance as a function of the phase angle between the pump and signal voltages. Bloom and Chang consider only signal voltages which pass through zero at alternate zeros of the pump.

We will write the signal and pump voltages as

$$V_1 \cos \omega_1 t$$

and

$$V_3 \cos (2\omega_1 t + \theta),$$

respectively. Their analysis[1] is for the special case $\theta = 0$. The inductance is assumed to have its flux ϕ and its current i related by

$$\phi = L_0 i - \mathfrak{L} i^2.$$

The inductance, the series resonant signal circuit, and the series resonant pump circuit are all connected in parallel as in Bloom and Chang. Small signal analysis gives the ratio of the resistance, R, inserted into the signal circuit by the action of the pump, to the resistance R_T of the signal circuit as

$$\frac{R}{R_T} = \beta \left[\frac{(1 + \beta^2) \sin \theta - 2\beta}{1 + \beta^2 - 2\beta \sin \theta} \right] \qquad (1)$$

where β is defined by

$$\beta = \frac{\omega_1 \mathfrak{L} V_3}{R_T R_3}.$$

R_3 is the resistance in the pump circuit.

For a nonlinear capacitance, having charge q and voltage v related by

$$v = S_0 q - \mathfrak{S} q^2$$

connected in parallel with the series resonant

* Received by the IRE, March 18, 1959.

[1] S. Bloom and K. K. N. Chang, "Theory of parametric amplification using non-linear reactances," *RCA Rev.*, vol. 18, pp. 578–593; December, 1957.

signal and pump circuits, the resistance ratio is

$$\frac{R}{R_T} = \frac{-\alpha[\cos\theta + 2\alpha + \alpha^2\cos\theta]}{(1+\alpha\cos\theta)^2} \quad (2)$$

where

$$\alpha = \frac{SV_3}{2\omega_1^2 R_T R_3}.$$

Eqs. (1) and (2) are plotted in Figs. 1 and 2 respectively. As the figures show, the

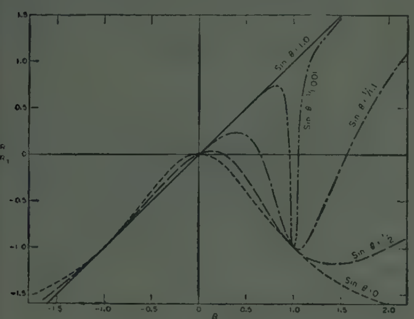

Fig. 1—R/R_T vs β for a degenerate parametric amplifier using a nonlinear inductance.

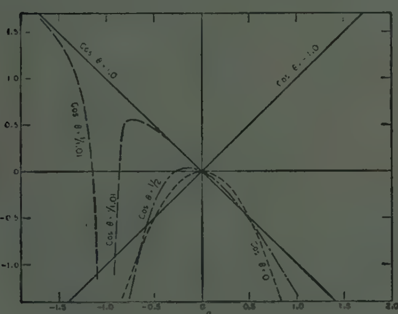

Fig. 2—R/R_T vs α for a degenerate parametric amplifier using a nonlinear capacitance.

oscillation point, $R/R_T = -1.0$, may or may not be sensitive to changes in θ, depending upon the signs of α and β. Actually, as R/R_T approaches -1.0, the analysis breaks down, since the small signal approximation no longer holds.

As would be expected, the phase θ does not appear in the expression for R in non-degenerate cases.

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An Iterative Method for Determining Ladder Network Functions*

Practical network designers almost never resort to the classical mesh or node equations to find the driving-point or transfer functions of ladder networks. Of the various "short-cuts" available, topological methods, such as signal-flow graphs[1] or Kirchhoff's rules[2] are most generally used. However, even these methods do not yield all the network functions simultaneously. For example, the Kirchhoff rule (or topological formula) used to determine, say, the driving-point admittance of a ladder is not applicable for the voltage-ratio transfer function. We would like to propose a simple construction method whereby it is possible to obtain every pertinent function network simultaneously. The method is based upon certain well-known relationships that exist between the branch currents and the node voltages of a ladder network.[3]

To illustrate the simplicity of the method, consider the general ladder structure in Fig. 1. In this representation, the series arms of the ladder are given as impedances while the shunt arms are represented as admittances. $V_a(s)$ is a node voltage,

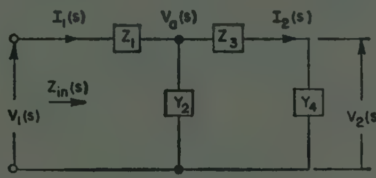

Fig. 1.

while $I_1(s)$, $I_2(s)$ are branch currents. For this network, the following relationships apply

$$V_2(s) = V_2(s) \quad (1)$$

$$I_2(s) = Y_4(s)V_2(s) \quad (2)$$

$$V_a(s) = I_2(s)Z_3(s) + V_2(s) = [1 + Z_3(s)Y_4(s)]V_2(s) \quad (3)$$

$$I_1(s) = Y_2(s)V_a(s) + I_2(s) = [Y_2(s)((1+Z_3(s)Y_4(s)) + Y_4(s)]V_2(s) \quad (4)$$

$$V_1(s) = I_1(s)Z_1(s) + V_a(s) = [Z_1(s)[Y_2(s)((1+Z_3(s)Y_4(s)) + Y_4(s)] + [1+Z_3(s)Y_4(s)]]V_2(s). \quad (5)$$

As we start from the end of the ladder and work towards the front, we see that each equation is obtained by multiplying the preceding equation by an immittance, and then adding to this result the equation twice preceding it. For example, (2) is derived from (1) by multiplying $V_2(s)$ by the immittance $Y_4(s)$. Eq. (3) is then obtained by multiplying (2) by the next immittance down the line, $Z_3(s)$, and then adding to this result, $V_2(s)$, from (1).

From this set of equations, we immediately obtain the network functions by taking ratios of the various equations. For example, the driving-point impedance, $Z_{in}(s)$, is obtained by dividing (5) by (4). The current-ratio transfer function $I_2(s)/I_1(s)$ is given as the ratio of (2) to (4). Moreover, if $V_2(s) = 1$, the equations are normalized. Eg. (5) is then simply the inverse of the voltage-ratio transfer function, $V_2(s)/V_1(s)$, while (4) is the inverse of the transfer impedance, $Z_{21}(s)$.

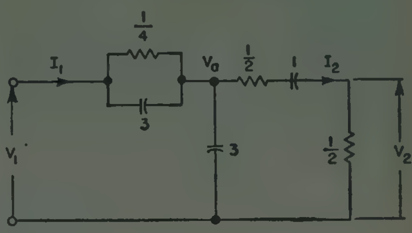

Fig. 2.

Consider the ladder network in Fig. 2. Here we see that

$$Y_4(s) = 2$$

$$Z_3(s) = \frac{1}{2} + \frac{1}{s} = \frac{s+2}{2s}$$

$$Y_2(s) = 3s$$

$$Z_1(s) = \frac{\left(\frac{1}{4}\right)\left(\frac{1}{3s}\right)}{\frac{1}{4} + \frac{1}{3s}} = \frac{1}{3\left(s+\frac{4}{3}\right)}.$$

The right-hand side of the equations can be written in the following triangular form:

$$\begin{array}{rl}
1 & V_2(s) \\
2 & I_2(s) \\
2\left[\frac{(s+2)}{2s}\right] + 1 = \frac{2(s+1)}{s} & V_a(s) \\
3s\left[\frac{2(s+1)}{s}\right] + 2 = 6\left(s+\frac{4}{3}\right) & I_1(s) \\
\frac{1}{3\left(s+\frac{4}{3}\right)}\left[6\left(s+\frac{4}{3}\right)\right] & \\
+ \frac{2(s+1)}{s} = \frac{4\left(s+\frac{1}{2}\right)}{s} & V_1(s).
\end{array}$$

Then the following network functions are obtained by inspection:

$$Z_{in}(s) = \frac{4\left(s+\frac{1}{2}\right)}{6s\left(s+\frac{4}{3}\right)}$$

$$\frac{I_2(s)}{I_1(s)} = \frac{1}{3\left(s+\frac{4}{3}\right)}$$

$$\frac{V_2(s)}{V_1(s)} = \frac{s}{4\left(s+\frac{1}{2}\right)}$$

$$Z_{21}(s) = \frac{1}{6\left(s+\frac{4}{3}\right)}.$$

One obvious advantage of this method is that it enables a teacher to create compli-

* Received by the IRE, April 7, 1959.

[1] S. J. Mason, "Feedback theory—some properties of signal flow graphs," Proc. IRE, vol. 41, pp. 1144–1156; September, 1953.

[2] W. Mayeda and S. Seshu, "Topological Formulas for Network Functions," Bulletin 446, Engrg. Experiment Station, University of Illinois, Urbana, Ill.; 1956.

[3] M. E. Van Valkenburg, "Network Analysis," Prentice-Hall Inc., Englewood Cliffs, N. J., pp. 233–234; 1955.

cated networks with simple driving-point impedances (by pole-zero cancellation in each line) for examination purposes.

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Another Approximation for the Alpha of a Junction Transistor*

Several approximations[1–4] have been put forward for the frequency variation of α, the common-base short-circuit current gain of a junction transistor. In the present author's opinion these are either too crude, and so misleading, or else too ingenious for general use. A useful approximation combines accuracy with simplicity, and the larger the product "accuracy × simplicity" the better. On this rating, it is felt that the approximation described below scores rather higher than any so far suggested.

We first state the expression to be approximated, then deduce the approximation, list its properties, and comment on them. Finally three other results of interest are appended.

The one-dimensional theory[5] provides us with the relations (assuming the collector multiplication factor is unity):

$$\alpha(\omega) = \gamma\beta(\omega) \tag{1}$$

$$\beta(\omega) = \operatorname{sech}\,[\eta(1 + j\omega\tau)^{1/2}], \tag{2}$$

where γ is the emitter efficiency, β the base transport factor; η equals $W/(D\tau)^{1/2}$, where W is the "electrical" base width, and D, τ are the "effective diffusion constant" and "effective lifetime"; $j\omega$ is the complex frequency variable.

It is known[6] that γ varies with frequency much less than does β, and so we assume that it remains constant at its low frequency value. This gives:

$$\frac{\alpha(\omega)}{\alpha_0} \simeq \frac{\beta(\omega)}{\beta_0} = \frac{\operatorname{sech}\,[\eta(1 + j\omega\tau)^{1/2}]}{\operatorname{sech}\,\eta}, \tag{3}$$

where α_0, β_0 are the low frequency values of α, β. Expanding gives

$$\frac{\beta(\omega)}{\beta_0} = 1 \Big/ \left[1 + \frac{j\omega\tau\eta^2\beta_0}{2!}\left(1 + \frac{\eta^2}{6} + \cdots\right) - \frac{\omega^2\tau^2\eta^4\beta_0}{4!}\left(1 + \frac{\eta^2}{10} + \cdots\right) + \cdots\right]. \tag{4}$$

This is the expression we want to approximate.

Eq. (3) plotted on the complex plane gives the well-known spiral,[7] and intuition suggested that a semicircle coinciding with the low frequency end of the spiral might provide the required approximation. The general form of a semicircle passing through the point (1,0) with center on the real axis is $z = (1 - jcm)/(1 + jm)$, where c is constant and m a parameter varying from 0 to $+\infty$. This may be expanded to give:

$$z = 1/[1 + jm(1 + c) - m^2c(1 + c) + \cdots]. \tag{5}$$

A direct comparison of (5) with (4) yields values for c and m, and if we assume $\beta_0 \simeq 1$, we obtain

$$\frac{\beta(\omega)}{\beta_0} \simeq \frac{1 - j\omega/5\beta_0\omega_s}{1 + j\omega/\omega_s}, \tag{6}$$

where

$$\omega_s = \frac{6}{5}\left(\frac{2D/W^2}{\beta_0}\right). \tag{7}$$

If we now put $\beta_0 = 1$ in the numerator of (6), we obtain, with small error, the following approximation[8] for α

$$\frac{\alpha(\omega)}{\alpha_0} \simeq \frac{1 - j\omega/5\omega_s}{1 + j\omega/\omega_s}. \tag{8}$$

The properties of this approximation are now briefly noted.

1) It has been shown[9] that for normal values of β_0,

$$\frac{\omega_\alpha}{1.216} = \frac{2D/W^2}{\beta_0},$$

where ω_α is the 3-db cutoff frequency. Hence $\omega_s = 0.987\omega_\alpha$, and for all practical purposes ω_α may be substituted for ω_s in the approximation. The origina form (8) is retained here for the sake of clarity.

2) The magnitude error at the cutoff frequency ω_α is 2 per cent; the error in phase angle is 2°. The errors rapidly become quite insignificant as the frequency is reduced.

3) The common emitter cutoff frequency deduced from the approximation is $\omega_s(1-\alpha_0)/(1+\alpha_0/5)$, compared with the true value[10] $\omega_\alpha' = \omega_s(1-\alpha_0)/1.2$.

4) The frequency at which the common emitter current gain $\alpha' = \alpha/(1-\alpha)$ is unity is $\omega_s/1.183$, compared with the true value[10] $\omega_1 = \omega_s/1.203$, *i.e.*, an error of 2 per cent.

5) The 3-db frequency of the approximation (8) is $1.043\omega_s$, compared with the true value $\omega_\alpha = 1.013\omega_s$, *i.e.*, an error of 3 per cent.

It is clear from 1)–4) above that only negligible errors are encountered for frequencies up to cutoff, whether or not ω_s is replaced by ω_α. Only if the approximation is used in reverse, 5), are discrepancies greater than 2 per cent. From 5) it appears that the 3-db frequency of the approximation is not exactly the 3-db frequency of the transistor, —and if ω_α replaces ω_s the situation seems paradoxical, if not intolerable. However, the paradox is easily resolved. The approximation is designed to be accurate at low frequencies, and so in this context ω_α is a constant characterizing the low frequency behavior, which itself happens to be defined by the high frequency behavior. For drift transistors ω_s and ω_α can differ considerably,[11] and the situation does not arise.

Switching

The applications of the approximation in the field of switching are of interest. The switching theory given by Moll[12] is based on the approximation $\alpha = \alpha_0/(1 + j\omega/\omega_\alpha)$ and if we replace this by the approximation (8), then we find *e.g.*, for the 0 to 90 per cent turn-on time, under the same conditions,

$$T_0 = \frac{1}{\omega_s}\ln\frac{1.2I_E}{I_E - 0.9I_C/\alpha_0} \simeq \frac{1}{5\omega_\alpha} + \frac{1}{\omega_\alpha}\ln\frac{I_E}{I_E - 0.9I_C/\alpha_0}, \quad \text{(common base)} \tag{9}$$

$$T_0 = \frac{1}{5\omega_s} + \frac{(1 + \alpha_0/5)}{\omega_s(1 - \alpha_0)}\ln\frac{I_B}{I_B - 0.9I_C/\alpha_0'} \simeq \frac{1}{5\omega_\alpha} + \frac{1.216}{\omega_\alpha(1 - \alpha_0)}\ln\frac{I_B}{I_B - 0.9I_C/\alpha_0'}, \quad \text{(common emitter)} \tag{10}$$

and similarly for common collector; here I_E and I_B are emitter and base currents after the input step is applied, and I_C is the collector current at the edge of Region III. These expressions differ from Moll's by including the "delay time,"[13] $1/5\omega_\alpha$, the same (roughly) for all three connections, and the factor[14] 1.216 in the common emitter and common collector connections.

Conclusion

It is suggested that the approximation described above gives an adequate description of the intrinsic frequency effects in a junction transistor, either in the original form (8), or in the form

$$\frac{\alpha(\omega)}{\alpha_0} = \frac{1 - j\omega/5\omega_\alpha}{1 + j\omega/\omega_\alpha}. \tag{11}$$

It is sufficiently accurate for practical purposes, and sufficiently simple to be easy to use.

Appendix

1) If we retain only the first two terms of (4) we have the simplest approximation

* Received by the IRE, April 3, 1959.

1 D. E. Thomas, "Transistor amplifier—cutoff frequency," Proc. IRE, vol. 40, pp. 1481–1483; November, 1952.

2 R. D. Middlebrook and R. M. Scarlett, "An approximation to alpha of a junction transistor," IRE Trans. on Electron Devices, vol. ED-3, pp. 25–29; January, 1956.

3 R. L. Pritchard, "Electric-network representation of transistors—a survey," IRE Trans. on Circuit Theory, vol. CT-3, pp. 5–21; March, 1956. See (8) and footnote 45.

4 A. B. Macnee, "Approximating the alpha of a junction transistor," Proc. IRE, vol. 45, p. 91; January, 1957.

5 W. Shockley, M. Sparks, and G. K. Teal, "P-N junction transistors," *Phys. Rev.*, vol. 83, pp. 151–162; July, 1951.

6 R. L. Pritchard, "Frequency variations of junction-transistor parameters," Proc. IRE, vol. 42, pp. 786–799; May, 1954.

7 For example, see "Principles of Transistor Circuits," R. F. Shea, Ed., John Wiley and Sons, Inc., New York, N. Y., p. 347; 1953.

8 This approximation is similar to that put forward by Middlebrook and Scarlett, *op. cit.* However, the aim, derivation and result are all different; moreover the method used here can be applied to the drift transistor (see footnote 11).

9 J. M. Rollett, "The characteristic frequencies of a junction transistor," *J. Electronics and Control*, vol. 5, p. 347; October, 1958.

10 From (7) and footnote 9.

11 J. M. Rollett, to be published.

12 J. L. Moll, "Large-signal transient response of junction transistors," Proc. IRE, vol. 42, pp. 1773–1784; December, 1954.

13 N. H. Enenstein, "A transient equivalent circuit for junction transistors," IRE Trans. on Electron Devices, vol. ED-4, pp. 37–54; December, 1953.

14 This factor is also found by R. Beaufoy and J. J. Sparkes, "The junction transistor as a charge controlled device," *A.T.E.J.*, vol. 13, pp. 310–327; October, 1957.

for both phase and magnitude of α, *i.e.*,

$$\frac{\alpha(\omega)}{\alpha_0} \simeq \frac{1}{1+j\beta_0\omega/(2D/W^2)} = \frac{1}{1+1.216j\omega/\omega_\alpha} = \frac{1}{1+j\alpha_0\omega/\omega_1}. \tag{12}$$

This is only useful for frequencies less than about $\omega_1/3$.

2) Taking the magnitude of (4), we find an approximation for the magnitude of α, *i.e.*,

$$\left|\frac{\alpha(\omega)}{\alpha_0}\right|^2 \simeq \frac{1}{1+\beta_0^2\omega^2/6(D/W^2)^2} \simeq \frac{1}{1+(\omega/\omega_\alpha)^2}. \tag{13}$$

This is useful for frequencies up to about $5\omega_\alpha$ and provides a justification for use of the expression $\alpha(\omega) = \alpha_0/(1+j\omega/\omega_\alpha)$.

3) If it is assumed that the only dissipative elements important at high frequencies are base resistance r_b and collector capacitance C_c, then the maximum frequency of oscillation ω_m is given by[15]

$$\omega_m = \frac{|\alpha|^2}{|\operatorname{Im}(\alpha)|}\cdot\frac{1}{4r_bC_c}, \tag{14}$$

where $\operatorname{Im}(\alpha)$ is the imaginary part of α. Substituting for $|\alpha|$ from (13) (since this gives the magnitude accurately at high frequencies), and for $\operatorname{Im}(\alpha)$ from (8), we obtain

$$\omega_m^2 = \frac{\alpha_0\omega_\alpha}{4.8r_bC_c}, \tag{15}$$

which can be written

$$\omega_m^2 = \frac{\alpha_0'\omega_\alpha'}{4r_bC_c} = \frac{\omega_1}{4r_bC_c}. \tag{16}$$

This result can also be obtained by using the approximation $\alpha' = \alpha_0'/(1+j\omega/\omega_\alpha')$ since $|\alpha|^2/\operatorname{Im}(\alpha) = |\alpha'|^2/\operatorname{Im}(\alpha')$, or by working directly from (4). In the second form, (16), it may be applied to drift transistors, since the approximation for α' still holds.[11,16]

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[15] This is found by putting the unilateral power gain equal to unity. See S. J. Mason, "Power gain in feedback amplifiers," IRE Trans. on Circuit Theory, vol. CT-1, pp. 20–25; June, 1954.

[16] R. C. Johnston, "Transient response of drift transistors," Proc. IRE, vol. 46, pp. 830–838; May, 1958.

The Significance of Transients and Steady-State Behavior in Nonlinear Systems*

Introduction

An often misused and apparently not well-understood concept concerns what is meant by transients and steady-state behavior in nonlinear systems. The notion of these terms seems vague to some even for linear systems. With the advent of systematic methods of analysis of nonlinear systems[1–6] recently published, it seems quite important to sharply define what is meant by transient and steady-state phenomena arising in nonlinear systems.

Significance in Linear Systems

The concept of transient phenomena arises naturally in linear systems and is therefore easily defined for such systems. Consider a linear system depicted by Fig. 1.

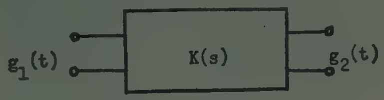

Fig. 1—A linear lumped parameter system.

The instantaneous response[7] of this system is given by (1)

$$g_2(t) = \int_0^t k(\tau)g_1(t-\tau)d\tau, \tag{1}$$

where

- $g_2(t)$ denotes the instantaneous time response,
- $k(t)$ denotes the impulse response of the linear system.
- $g_1(t)$ denotes the instantaneous forcing function.
- s denotes the complex frequency variable.
- t, τ denote time variables.

The function $g_1(t)$ satisfies the condition

$$g_1(t)\begin{cases} =0 & \text{for } t<0 \\ \neq 0 & \text{for } t>0. \end{cases}$$

We may regard (1) as the total response of the linear system. Now we note that the integral of (1) may be written as the difference of two integrals, namely

$$\int_0^t k(\tau)g_1(t-\tau)d\tau = \int_0^\infty k(\tau)g_1(t-\tau)d\tau - \int_t^\infty k(\tau)g_1(t-\tau)d\tau. \tag{2}$$

Eq. (2) follows from the definition of the integral.[8] The first term of the right member is recognized as the steady-state term since (3) is the response in the Fourier convolution sense.

$$\int_{-\infty}^\infty k(\tau)g_1(t-\tau)d\tau = \int_0^\infty k(\tau)g_1(t-\tau)d\tau \tag{3}$$

in which we note $g_1(t) = 0$ for $t<0$.

The second term of the right member of (2) is therefore the transient term. This result follows from the notion that the total response of a linear system is composed of transient and steady-state terms only.

If we let $g_{2T}(t)$ denote the transient term and $g_{2S}(t)$ denote the steady-state term, then

$$g_{2T}(t) = \int_t^\infty k(\tau)g_1(t-\tau)d\tau \tag{4}$$

and

$$g_{2S}(t) = \int_0^\infty k(\tau)g_1(t-\tau)d\tau. \tag{5}$$

Eq. (2) written in terms of (4) and (5) is

$$g_2(t) = g_{2S}(t) - g_{2T}(t). \tag{6}$$

For Nonlinear Systems

It is evident therefore that the transient and steady-state behavior is defined for linear systems. The question now arises as to what these mean in a nonlinear system. To begin with we must recognize that a linear system is a special case of a class of nonlinear systems. Thus any definition of transient and steady-state phenomena must be consistent with (4) and (5) and indeed reduce to (6) in the limiting case.

Consider Fig. 2. The transmission char-

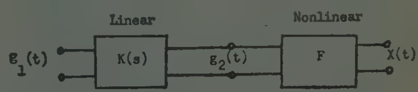

Fig. 2—A nonlinear system with F belonging to the functional class.

acteristics of the nonlinear components are assumed to belong to the functional class.[1,2] Wolf[2] shows that the polynomial belongs to this class under certain conditions. Therefore

$$X(t) = \sum_{k=0}^M a_k g_2^k(t) \tag{7}$$

is a possible form of $F\{g_2\}$. Other forms of $F\{g_2\}$ may involve polynomials of derivatives of $g_2(t)$ and products of derivatives and the various degrees of the function. The degree of (7) is denoted by M. We suppose without loss of generality that F does not load $K(s)$. Under these conditions the output $X(t)$ can be written as (8) in terms of (4) and (5) as follows with the aid of the binomial theorem.

$$X(t) = \sum_{k=0}^M \sum_{n=0}^k a_k(-1)^n \binom{k}{n} g_{2S}^{k-n} g_{2T}^n; \qquad \binom{k}{n} = \frac{k!}{n!(k-n)!}. \tag{8}$$

To display the transient and steady-state terms as defined for linear systems $X(t)$ is expanded as follows

$$X(t) = \sum_{k=0}^M \left\{ a_k g_{2S}^k + (-1)^k a_k g_{2T}^k + \sum_{n=1}^{k-1} a_k(-1)^n \binom{k}{n} g_{2S}^{k-n} g_{2T}^n \right\}, \tag{9}$$

[1] A. A. Wolf, "A Mathematical Theory for the Analysis of a Class of Nonlinear Systems," Ph.D. dissertation, University of Pennsylvania, Philadelphia, Pa.; June, 1958.

[2] A. A. Wolf, "Recurrence relations in the solution of a class of nonlinear systems," AIEE Summer Meeting, paper no. 57-864, June, 1957. To be published in *Trans. AIEE;* 1959.

[3] A. A. Wolf, "Generalized relations in the solution of physical nonlinear systems," AIEE Winter Meeting, paper no. 58-437; February, 1958.

[4] A. A. Wolf, "Analysis of transcendental nonlinear systems," AIEE Summer Meeting, paper no. 58-995; June, 1958.

[5] Y. H. Ku and A. A. Wolf, "A stability criterion for nonlinear systems," AIEE Winter Meeting, paper no. 59-23; February, 1959. To be published in *Trans. AIEE;* 1959.

[6] Y. H. Ku, A. A. Wolf, and J. H. Dietz, "Taylor-Cauchy transforms for the analysis of a certain class of nonlinear systems," 1959 IRE National Convention Record, pt. 2, pp. 49–61.

[7] Eq. (1) can be written as

$$g_1(t) = \int_0^t g_1(\tau)k(t-\tau)d\tau.$$

[8] E T. Wittaker and G. N. Watson, "A Course of Modern Analysis," Cambridge University Press, Cambridge, Eng.; 1927.

* Received by the IRE, March 31, 1959.

or

$$X(t) = \sum_{k=0}^{M} a_k g_{2S}^k + \sum_{k=0}^{M} a_k g_{2T}^k + \sum_{k=0}^{M} \sum_{n=1}^{k-1} a_k(-1)^n \binom{k}{n} g_{2S}^{k-n} g_{2T}^n. \quad (9a)$$

It is clear therefore that the first term of the right member is the steady-state term and the second term of the right member is the transient term. We see in addition that some new terms appear in the nonlinear system which did not appear in the linear system. These new terms will be denoted as the "Cross-Product" terms. We further note that (9a) is consistent with (6) in the limiting case when $M \leq 1$.

Conclusions and Discussion

The total instantaneous response of a linear system is defined by a transient and steady-state behavior only while a nonlinear system cannot be described by these alone. Another behavior must be considered, namely that arising from the cross-product terms. If one is tempted to call the cross-product terms either steady-state or transient, he immediately is inconsistent with the well-defined concept of these terms in linear systems. It is therefore not enough to think of transients as phenomena which either die out or grow with time.

From the previous development we note the following relations:

Linear System:

Total Instantaneous Response = Steady-State Response − Transient Response. (10)

Nonlinear System:

Total Instantaneous Response = Steady-State Response − Transient Response + Cross Product Response. (11)

It is easy to show that (11) is true of all nonlinear systems.

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Ten Years of a "Multi-Port" Terminology for Networks*

Recently I have received some inquiries as to the origin of the term "port" in the field of networks. Some of our readers may be interested in my original approach to this topic. This is best reviewed by quoting from a paper by David Dettinger and the writer, which was printed in the form of a monograph and also was presented at the IRE Convention in 1949 [1]:

A new terminology for multi-port networks. In the present discussion, the writer is introducing a new terminology to fill a long-felt need. It is found especially helpful in the treatment of converters.

It has been customary to designate each entrance or exit of a network as a pair of terminals, based on the circuit concept of wires and conduction. The result was cumbersome terms such as "four-terminal networks." The ultimate confusion was caused by the term "two-terminal-pair" with the unobvious meaning of a network with two pairs of terminals. Furthermore, the terminal-pair concept becomes artificial in the case of electromagnetic fields transmitting power within boundaries, through holes, and from one region to another in space.

After considering many alternatives, the writer has adopted the term "portal" or simply "port" as the general designation of an entrance or exit of a network. A self-impedance becomes a "one-port." The usual transducer becomes a "two-port" with one "in-port" and one "out-port." The general network is designated a "multi-port." This plan has received a favorable reaction from the several engineers to whom it has been presented, and is first put to use in this monograph.

In the short space of one decade, this terminology has been accorded increasing acceptance, largely through its adoption by the active theoretical group in the Microwave Research Institute of the Polytechnic Institute of Brooklyn. Two years ago, the term "port" was formally defined in IRE Standards [3]. Just recently, it has first appeared in a complete textbook [4]. Considering the long usage of the previous terminology, it is gratifying that the transition to "ports" has progressed so far in so short a time.

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* Received by the IRE, April 9, 1959.

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[1] D. Dettinger and H. A. Wheeler, "Measuring the Conversion Efficiency of a Superheterodyne Converter by the Input Impedance Circle Diagram," Wheeler Monographs, No. 9, March, 1949. Presented at the 1949 IRE Convention, New York, N. Y.; abstract, Proc. IRE, vol. 37, p. 162; February, 1949.
[2] "Reference Data for Radio Engineers," 4th ed., IT&T Corp., p. 646; 1956.
[3] "IRE Standards on Electron Tubes: Definition of Terms, 1957," Proc. IRE, vol. 45, pp. 983–1010; July, 1957. Also, "IRE Standards on Antennas and Waveguides: Waveguide and Waveguide Component Measurements," Proc. IRE, vol. 47, pp. 568–582; April, 1959.
[4] N. Balabanian, "Network Synthesis," Prentice-Hall, Inc., New York, N. Y., 1958.

WWV Standard Frequency Transmissions*

Since October 9, 1957, the National Bureau of Standards radio stations WWV and WWVH have been maintained as constant as possible with respect to atomic frequency standards maintained and operated by the Boulder Laboratories, National Bureau of Standards. On October 9, 1957, the USA Frequency Standard was 1.4 parts in 10^9 high with respect to the frequency derived from the UT2 second (provisional value) as determined by the U. S. Naval Observatory. The atomic frequency standards remain constant and are known to be constant to 1 part in 10^9 or better. The broadcast frequency can be further corrected with respect to the USA Frequency Standard, as indicated in the table; values are given as parts in 10^{10}. This correction is *not* with respect to the current value of frequency based on UT2. A minus sign indicates that the broadcast frequency was low.

The WWV and WWVH time signals are synchronized; however, they may gradually depart from UT2 (mean solar time corrected for polar variation and annual fluctuation in the rotation of the earth). Corrections are determined and published by the U. S. Naval Observatory.

WWV and WWVH time signals are maintained in close agreement with UT2 by making step adjustments in time of precisely plus or minus twenty milliseconds on Wednesdays at 1900 UT when necessary; no time adjustment was made during this month at WWV and WWVH.

* Received by the IRE, August 24, 1959.

WWV Frequency†

1959		#1	#2	#3
July	1	−31	−33	−29
	2	−32	−35	−31
	3	−32	−32	
	4	−31	−32	
	5	−30	−32	
	6	−30	−32	−28
	7	−30	−32	−29
	8	−30	−32	−28
	9	−30	−32	−29
	10	−30	−32	−29
	11	−30	−32	
	12	−30	−32	
	13	−30	−32	−29
	14	−30	−32	−27
	15	−30	−32	−28
	16	−30	−32	−27
	17	−30	−32	−27
	18	−30	−32	
	19	−30		
	20	−30	−32	−29
	21	−30	−32	−29
	22	−30	−32	−29
	23	−30	−32	−29
	24	−30	−32	−27
	25	−30	−32	
	26	−30	−32	
	27	−29	−32	−28
	28	−29	−32	−28
	29	−29	−32	−29
	30	−29	−31	−28
	31	−29	−32	−28

† WWVH frequency is synchronized with that of WWV.

Column #1 Vs NBS‡ atomic standards, Boulder, Colo., 30-day moving average seconds pulses at 15 mc.

Column #2 Vs atomichron at WWV. measuring time one hour at 2.5 mc.

Column #3 Vs atomichron at the U. S. Naval Research Laboratory, Washington, D. C., measuring time 56 minutes at 2.5 mc.

‡ Method of averaging is such that an adjustment of frequency of the control oscillator appears on the day it is made. No adjustment was made during July.

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He was assistant to a patent attorney in that city in 1938. From 1939 to 1940, he worked in the Laboratory of Scientific Acoustics, Ltd., in London, England. After one year with Associated Research, Inc., in Chicago, Ill., he joined the research group of Zenith Radio Corporation in the same city in 1941. He became Zenith's Associate Director of Research in 1952. His previously published work in the vacuum-tube field includes the development of the phasitron modulator, of receiving tubes such as the 6BN6 and 6AR8, and of transverse field traveling-wave tubes.

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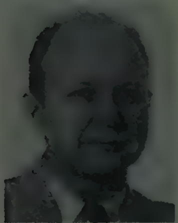
❖

L. J. Anderson was born in Salt Lake City, Utah, in 1917. He received the A.B. degree in 1939, and the M.A. degree in 1942, both from the University of California, Los Angeles.



L. J. Anderson

From 1942 to 1955 he was a physicist at the United States Naval Electronics Laboratory, San Diego, Calif., where he worked on tropospheric propagation problems, particularly the effects of the lower atmosphere on propagation. He was responsible for developing methods of predicting radio-radar propagation from routine meteorological data, and was also engaged in meteorological instrumentation for propagation purposes. Prior to 1955, he directed the Environment Studies Branch at the Naval Electronics Laboratory. Then, in 1955, he joined colleagues in forming Smyth Research Associates, where he is continuing his work on tropospheric propagation and allied studies.

Mr. Anderson is a member of U.S.A. Commission II of URSI, the American Meteorological Society, and the American Chemical Society.

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Julian J. Bussgang (A'52–M'55–SM'58) was born in Lwow, Poland, on March 26, 1925. He received the B.Sc. (Eng.) degree from the University of London, London, Eng., in 1949, after attending Politecnico di Torino, Italy, for one year. He received the M.S. degree in electrical engineering from the Massachusetts Institute of Technology, Cambridge, in 1951 and the Ph.D. degree in applied physics from Harvard University, Cambridge, Mass., in 1955.

J. J. Bussgang

While attending M.I.T., he was with the Research Laboratory of Electronics. From 1952 to 1953 he was connected with the Lincoln Laboratory, Lexington, Mass. In 1954 he was on the research staff of the Gordon McKay Laboratory at Harvard.

He joined the Radio Corporation of America in 1955. He has worked on radar design, statistical detection theory, nonlinear systems analysis, frequency modulation, and coding. He is at present manager of applied research in the RCA Missile Electronics and Controls Department, Burlington, Mass.

Dr. Bussgang is a member of Sigma Xi, the IEE, and the Society for Industrial and Applied Mathematics.

❖

B. G. Firth was born in Kearny, N. J., on January 28, 1902. He graduated from the engineering training course of the Bell Telephone Laboratories, New York, N. Y., in 1924.

B. G. Firth

He remained at the Bell Telephone Laboratories for eleven years, where he worked mostly on vacuum tube research and development, and associated problems. In 1935 he joined the Electronic Tube Division of Tung-Sol Electric, Inc., Bloomfield, N. J., where in 1942 he assisted in the formation of the Tung-Sol Research Lab. He has been with Tung-Sol for twenty-four years, working on practically all phases of vacuum tube research and development, including electronic ignition and hot and cold cathode and vacuum and gas filled tubes.

❖

Louis Essen was born in Nottingham, England, in 1908. He received the B.S. degree in physics from London University, England, in 1928. After a short period of post-graduate study at University College, Nottingham, he joined the National Physical Laboratory, Teddington, England, where he is now a Senior Principal Scientific Officer.

L. Essen

While with the Laboratory, he received the Ph.D. and D.Sc. degrees in 1941 and 1948, respectively, from London University. He has worked on quartz clocks, the velocity of electromagnetic waves, the refractive index of gases, and measurements at microwave frequencies.

Dr. Essen is a member of the Order of the British Empire.

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Joseph H. Holloway was born in Cleveland, Ohio, on July 31, 1929. He received the B.S. degree from the Massachusetts Institute of Technology, Cambridge, and the B.A. degree from Wooster College, Wooster, Ohio, simultaneously in 1952 on a combined study plan, and the Ph.D. degree in physics from the Massachusetts Institute of Technology in 1956.

J. H. Holloway

Since that time, he has been with the National Company, Malden, Mass., where he has been concerned primarily with the development of atomic beam frequency standards.

Dr. Holloway is a member of the American Physical Society.

❖

George W. Hrbek (A'53–M'57) was born on December 27, 1927 in Oak Park, Ill. He received the B.S. degree in electrical engineering from the Illinois Institute of Technology, Chicago, in January, 1953.

G. W. Hrbek

From 1953 to 1954, he was associated with the Electron Tube Division of Sperry Gyroscope Co., where he worked on traveling-wave tubes and related microwave-tube problems. From 1954 to 1956 he served in the U. S. Army Signal

Corps. Since 1956, he has been a research engineer at the Zenith Radio Corporation, Chicago, Ill., working in the field of transverse-field traveling-wave tubes and transverse-field parametric amplifier tubes.

Mr. Hrbek is a member of Eta Kappa Nu.

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Daniel Leenov was born in Washington, D. C., on April 10, 1923. He received the B.S. degree in chemistry from George Washington University, Washington, D. C., in 1943. He began graduate work at the University of Chicago, Chicago, Ill., in 1946, receiving the M.S. and Ph.D. degrees in physics in 1948 and 1951.

D. LEENOV

From 1943 to 1945 he was a research associate on a National Defense Research Committee rocket project at George Washington University. He taught in the Physics Department of Roosevelt College from 1951 to 1952, and in the College of the University of Chicago from 1952 to 1955. From 1955 to 1956 he was an assistant professor in the Department of Physical Science and in the Department of Physics at the University of Florida. He joined the technical staff of the Bell Telephone Laboratories in 1956, where he has been associated with the microwave diode group.

Dr. Leenov is a member of the American Physical Society and Sigma Xi.

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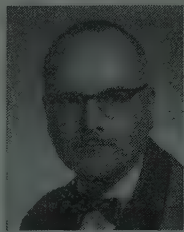
Walter A. Mainberger (S'43–A'45–M'51–SM'57) was born in Würzburg, Germany, on June 28, 1922. He received the B.E.E. degree from the College of the City of New York, N. Y., in 1943. After serving two years in the U. S. Navy as a radio technician, he was employed for five years by the Federal Telecommunications Laboratories, where he worked on instrument landing and omnirange systems and helped develop the prototype TACAN system. He received the M.E.E. degree from New York University, N. Y., in 1951, and that same year joined the W. L. Maxson Company where he helped develop a radar map-matching navigational computer. In 1955, he joined the National Company, Malden, Mass., where he has since been engaged mainly in the development and production of atomic frequency standards and is now manager of the Electronic Systems Department.

W. A. MAINBERGER

Mr. Mainberger is a registered Professional Engineer in Massachusetts.

Donald W. Mayer was born in Philadelphia, Pa., in 1919. He received the B.Sc. degree from the Philadelphia College of Pharmacy and Science in 1941.



D. W. MAYER

He joined the research laboratory of John Wyeth & Company until called to military service in 1942. In 1946 he entered the research laboratory of Merck & Company where he remained until 1950, at which time he became associated with Tung-Sol Electric, Bloomfield, N. J., as a research chemist. His first problems were on the screening of black and white TV tubes. Later he was engaged in work on semiconductor, color television, and finally, the MgO cold cathode project.

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Viktor Met was born on September 10, 1928, in Vienna, Austria. He received the Dipl.Ing. from the Technische Hochschule, Vienna, in 1952 and was the recipient of a Fulbright Travel Grant in the same year. He received the M.S. degree in electrical engineering in 1953 from the University of Minnesota, Minneapolis, during which time he was a teaching assistant at the University.

V. MET

Upon his return to Austria, he became a research assistant at the Technische Hochschule and received the Dr. techn. degree in 1955. Since November, 1955, he has been a member of the technical staff at the General Electric Microwave Laboratory in Palo Alto, Calif.

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Paul Nesbeda was born on June 20, 1921, in Trieste, Italy. He received the Dr. Math. Sciences degree from the University of Pisa, Italy, in 1943. From 1943 to 1952 he was engaged in teaching and research in theory of functions, calculus of variations, and integration theory at the University of Trieste, Italy, the Catholic University of America, Washington, D. C., the University of Paris, Institut H. Poincaré, and the Institute for Advanced Study, Princeton, N. J.

P. NESBEDA

In 1952 he joined RCA Victor Division in Camden, N. J., where he worked in the application of statistical estimation to the fields of communication and radar detection. Since 1958 he has been leader of the Applied Mathematics Group at the Missile Electronics and Controls Department of RCA in Burlington, Mass.

Dr. Nesbeda is a member of the American Mathematical Society, the Mathematical Association of America, the Institute of Mathematical Statistics, the Society for Industrial and Applied Mathematics, and Sigma Xi. He is also listed in "American Men of Science."

❖

J. V. L. Parry was born on September 12, 1923, in Mountain Ash, Wales. He received the B.S. degree, and, in 1942, the M.S. degree from University College, Cardiff, Wales.

J. V. L. PARRY

From 1943 to 1946, he was engaged in radar research at the Royal Radar Establishment. He was at the National Physical Laboratory, Teddington, Middlesex, England, from 1946 to 1958, where he worked on dielectric measurements, microwave measurements, and atomic standards. Mr. Parry is presently the principal physicist at the Diffusion Plant of the Atomic Energy Authority, Capenhurst, Cheshire, England.

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Friedrich H. Reder (A'54) was born in Garsten, Upper Austria, on December 9, 1919. He received the cand. ing. degree in technical physics from the Institute of Technology, Graz, Austria, in 1947, and the Ph.D. degree in physics from the University of Graz in 1949.

F. H. REDER

From 1948 to 1950, he was at the University of Graz, where he was engaged in work on microwave cavity methods for determining the dielectric constant of solids and liquids, and in work on interference microscopy. From 1950 to 1951, he was with the Massachusetts Institute of Technology, Cambridge, where he was a research fellow engaged in work on microwave gas discharge phenomena in pure He gas. From 1951 to 1953, he worked on gas discharge projects and high-vacuum techniques at the University of Graz and at the Shell Research Laboratory, Amsterdam, The Netherlands. Since 1953 he has been with the Frequency Control Division of the U. S. Army Signal Research and Development Laboratories, Fort Monmouth, N. J., where he is now in charge of research and development work in atomic and molecular frequency control.

Dr. Reder is a member of the American Physical Society.

Harris Safran was born in Denver, Colo., on April 28, 1923. He received the B.S. degree in physics in 1948, and the M.S. degree in mathematics in 1949, both at the University of Utah, Salt Lake City. From 1949 to 1952 he continued graduate study in mathematics at Harvard University, Cambridge, Mass.

H. Safran

From 1952 to 1955 he worked in the fields of guided missiles, and guidance and control, at the Massachusetts Institute of Technology, Cambridge.

Since 1955, Mr. Safran has been at RCA Missile Electronics and Controls Department, Burlington, Mass., working in the fields of systems analysis and radar.

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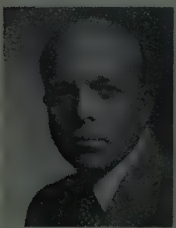
A. Melvin Skellett (M'44–SM'50–F'56) was born in St. Louis, Mo., on July 14, 1901. He received the A.B. and M.S. degrees in physics in 1924 and 1927, respectively, both from Washington University, St. Louis, Mo., and the Ph.D. degree in astronomy from Princeton University, Princeton, N. J., in 1933.



A. M. Skellett

After two years at the University of Florida, Gainesville, where he held the positions of assistant professor of physics and chief engineer of the state-owned radio station WRUF, he joined the technical staff of Bell Telephone Laboratories. Fifteen years later he left Bell to become director of research and vice-president of National Union Radio Corporation where he also served on the Board of Directors. He holds 80 U. S. patents, and served for a number of years as consultant to the Department of Defense of the U. S. Government. In 1955, he joined Tung-Sol Electric, Inc., Bloomfield, N. J., where he is presently employed as director of research.

Dr. Skellett is a life member of the American Astronomical Society, and a member of the American Physical Society, American Ordnance Association, and Sigma Xi.

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Arthur Uhlir, Jr. (A'53–SM'58) was born in Chicago, Ill., on February 2, 1926. He received the B.S. and M.S. degrees in chemical engineering from the Illinois Institute of Technology, Chicago, in 1945 and 1948, respectively, and the S.M. and Ph.D. degrees in physics in 1950 and 1952, respectively, from the University of Chicago, where he was an AEC predoctoral fellow from 1949 to 1951.

A. Uhlir, Jr.

He was a process analyst at Douglas Aircraft Co., Chicago, Ill., in 1945. From 1945 to 1948, he was engaged in fluid mechanics research at Armour Research Foundation. In 1951, he joined the Transistor Development Department of Bell Telephone Laboratories. There he worked on point-contact transistor theory, semiconductor surface protection, and electrochemical properties of semiconductors, and developed an electrolytic micromachining technique for metals and semiconductors. He was also engaged in work on microwave semiconductor devices. Since September, 1958, he has been with Microwave Associates, Burlington, Mass.

Dr. Uhlir is a member of the American Physical Society, Sigma Xi, Phi Lambda Upsilon, and the American Association for the Advancement of Science.

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S. H. Unger (S'47–M'57), for a photograph and biography, please see page 1767 of the October, 1958 issue of Proceedings.

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Glen Wade (S'51–A'54–SM'57) was born in Ogden, Utah, on March 19, 1921. He received the B.S. and M.S. degrees in electrical engineering from the University of Utah, Salt Lake City, in 1948 and 1949, respectively. He did graduate study at Stanford University, Stanford, Calif., where he was first a Sperry Fellow and then an RCA Fellow in Electronics, receiving the Ph.D. degree in 1954.

G. Wade

He had worked for a year at the Naval Research Laboratory in Washington, D. C., and after receiving the Ph.D., was employed as a research associate by the General Electric Microwave Laboratory at Stanford. At present he is an associate professor of electrical engineering at Stanford and a senior staff member of the Stanford Electronics Laboratories.

Dr. Wade received an Eta Kappa Nu Award in the "Outstanding Young Electrical Engineer" competition in 1955. He is a member of the American Physical Society, Phi Kappa Phi, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.

❖

Steven Weisbrod (S'49–A'50–M'55), was born in Warsaw, Poland, on July 30, 1925. He came to the United States in 1939, and received the B.S. degree in physics in 1949 from the California Institute of Technology, Pasadena, and the M.S. degree in engineering in 1959, from the University of California, Los Angeles.

S. Weisbrod

During World War II, he served with the American expeditionary forces in Europe, and, from 1949 to 1955, was employed as a physicist at the Navy Electronics Laboratories in San Diego, Calif. During that time he specialized in the problems of ionospheric radio propagation, backscatter and diversity systems. In 1953, for his work on the high-frequency backscatter system, he received the Navy Superior Accomplishment Award. In 1955, together with some of his colleagues, he helped form Smyth Research Associates in San Diego, Calif. He is now senior physicist there and, in this capacity, is continuing basic research in the field of ionospheric physics, electromagnetic wave propagation and meteor and field aligned scatter, and has written a number of papers on these subjects.

Mr. Weisbrod is a member of the American Mathematical Society.

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Gernot M. R. Winkler was born on October 17, 1922 in Frohnleiten, Austria. He attended the Realgymnasium in Graz, Austria, and received the Ph.D. degree from the University of Graz in 1952.

G. M. R. Winkler

In 1949, he joined the Solar Observatory, Kanzelhoehe, and later worked at the Astronomical Observatory, Graz, where he became assistant to the director. He came to this country in 1956 and has been working since at the U. S. Army Signal Research and Development Laboratories, Fort Monmouth, N. J., in the field of precision frequency control. He is presently Consultant of the Atomic Resonance Branch of the Frequency Control Division.

Scanning the Transactions

Experiments with teaching machines are proving them to be dramatically effective. Automated teaching systems have several very important advantages over conventional methods of instruction: 1) They provide every student information feedback that is individually tailored to his particular response. 2) They provide this information immediately. 3) The teaching process is individually geared to the learning pace of each student. Although the experimental machines in use now are simple—even crude—their superiority over standard classroom techniques has been clearly proven. Machines have taught first semester German in 40 hours and a college algebra course in 30 hours. When a college psychology course was recently automated, the standard final exams had to be revised because the median final score was 94 per cent, with no student making less than 85 per cent in the course. The only criticism reported came from college juniors taking an automated physical chemistry course at The Ohio University—they complained that the course was too easy! There is much yet to be learned in this infant field about programming techniques and machine requirements. It is an area that electronics people will be intimately associated with, requiring teachers to experiment and engineers to develop required teaching devices, and last but not least, eventually involving electronics students in their classrooms. (R. F. Mager, "Preliminary studies in automated teaching," IRE TRANS. ON EDUCATION, June, 1959.)

Talking to yourself is not necessarily as easy as you think. Psychoacoustic studies have shown that in order to speak freely and normally the average person has to be able to hear what he is saying. Along these lines, Marvin Camras reports an interesting incident which occurred when a wire recording was being monitored as it was being made, with the pickup head spaced a fraction of a second after the recording head. An announcer accidentally put on the monitoring headphones while he was speaking. He heard his own voice, to be sure, but what he heard was completely out of phase with what he was saying. The effect was so unexpected and overwhelming that he became absolutely speechless. The headphones were tried on others, with the same result—they became powerless to speak. In fact, a few small wagers were won from the uninitiated who thought they could recite a short paragraph while wearing the magic headphones. Dr. Camras adds that later studies by others showed that there are differences among individuals in the degree of confusion generated by delayed listening, with women seeming to be less susceptible than men. This would seem to support the theory that the more voluble talkers among us never listen to themselves. If true, this might explain one of nature's most puzzling and common phenomena—two women talking to each other simultaneously, and yet hearing every word the other said. ("The Editor's Corner," IRE TRANS. ON AUDIO, July-August, 1959.)

Microminiaturization is rapidly becoming an outmoded word as the density of component packaging increases by leaps and bounds. We have now reached the point where we can cram 50,000 parts in one cubic foot of space. How much more "miniature" do we expect to get? Now the experts are talking about densities ten times as great—and in only 3 to 5 years. In fact, a few special units, consisting of resistors, capacitors and transistors, have already been built in the 500,000 to 700,000 parts-per-cubic foot range. Indeed , we are approaching the time when the average volume of a single component will be 10^{-6} ft^3, or a *micro*cubic foot, so to speak. Too bad we didn't save the word "*micro*miniature" for that day. (S. F. Danko and V. J. Kublin, "Micro-modules: component parts and material requirements," IRE TRANS. ON PRODUCTION TECHNIQUES, August, 1959.)

Should we say "monaural?" The term really means "one-eared." Maybe "monophonic" would be more accurate. (P. W. Klipsch, "Wide-stage stereo," IRE TRANS. ON AUDIO, July-August, 1959.)

A new type of ferrite switch has been proposed that operates by reflection rather than absorption. The switching ratio is high (60 db) and the bandwidth is determined mainly by the applied magnetic field. These characteristics differ considerably from those of conventional absorptive ferrite switches. The switch takes the form of a ferrite slab imbedded in a circular waveguide, and among its many interesting applications are tunable cutoff filters, antenna switching, and AGC systems. (R. F. Soohoo, "A ferrite cutoff switch," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, July, 1959.)

A Solid-State issue of TRANSACTIONS has just been published by one of the Professional Groups—not the Electron Devices Group, as one might think, but the PG on Nuclear Science. The field of nuclear science is principally one of instrumentation and control, and thus has become especially fertile ground for exploiting the several and varied capabilities of solid-state devices. These devices have intriguing potentialities for the detection of neutron flux and other forms of radiation, and for use in all types of associated circuits, ranging from direct-current amplifiers of great sensitivity to pulse amplifiers and switching circuits operating at megacycle rates. They can also be used as switches, controlling large amounts of power, and thus are a potential replacement for relays. It is worthy of note that nuclear science is by no means the only field in which the solid state is having a field day. A review of last year's major advances in the microwave field, for example, shows that solid-state developments overshadowed all else, due to progress in solid-state masers and, especially, various forms of parametric amplifiers for generation and low-noise amplification at microwave frequencies. The stream of solid-state advances runs broad and deep indeed. (Solid-State Issue, IRE TRANS. ON NUCLEAR SCIENCE, June, 1959; R. E. Beam and M. E. Brodwin, "Report of advances in microwave theory and techniques in U.S.A.—1958, "IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, July, 1959.)

The ingenuity of man in simulating conditions he expects to encounter or wants to investigate is admirably illustrated by the variety of simulation devices that have been developed in the military electronics field. A sampling of eight simulation techniques are presented in a recent issue of TRANSACTIONS. Running through the list we find that devices, largely electronic in nature, have been developed to train celestial navigators, helicopter pilots and space crews. Simulated radar displays are described that can train radar operators to identify terrain features from the air and to track targets from the ground. One simulator even prepares a three-dimensional model of the terrain from a topographic map. (IRE TRANS. ON MILITARY ELECTRONICS, July, 1959.)

O-guide and X-guide will now have to be added to G-line and H-guide as a part of the microwave engineer's working vocabulary. The surface-wave transmission line, originally dubbed the G-line, has taken on more sophisticated and electrically efficient forms. The O-guide consists of a hollow cylindrical structure made of a thin dielectric sheet. The X-guide, as might be guessed, is a dielectric structure with an X-shaped cross section. These new surface-wave lines are being proposed for use in the SHF region, where they exhibit

a lower loss than do coaxial lines, G-lines, H-guides and rectangular waveguides. (M. Sugi and T. Nakahara, "O-guide and X-guide: An advanced surface wave transmission concept," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, July, 1959.)

Recent applications of circuits tend to demand more and more knowledge of how to switch effectively between different transmission properties and how to obtain directional selectivity in a network. The first of these problems involves the theory of varying parameter systems, and the second that of nonreciprocal systems. In an important subclass the first problem leads to two-state networks in which the parameters are changed between two sets of values by a bias control, while the second leads to two-port networks with unequal transmittance functions for the two directions of propagation. To define a figure of merit for networks from the point of view of such applications, the scattering matrix notation may be effectively employed. In the switched case, the scattering matrices before and after switching should show maximum difference between corresponding elements, while in the nonreciprocal case, maximum difference between off-diagonal elements of a single two-by-two scattering matrix is sought. Schaug-Pettersen and Tonning have shown how these differences may be maximized by lossless reciprocal imbedding of the given network and that the best possible result in both cases depends monotonically on a characteristic positive real parameter which is invariant to such transformation. This parameter is related to the invariant found by S. J. Mason in his study of power gain in feedback amplifiers. A figure of merit for state separability and nonreciprocality of devices and materials can thereby be defined and canonical procedures for obtaining the optimum performance in individual cases can be established. (Schaug-Petterson and A. Tonning, "On the optimum performance of variable and nonreciprocal networks," IRE TRANS. ON CIRCUIT THEORY, June, 1959.)

Books

The Upper Atmosphere, by H. S. W. Massey and R. L. F. Boyd

Published (1959) by the Philosophical Library, Inc., 15 E. 40 St., N. Y. 16, N. Y., 325 pages +7 index pages +1 bibliography page +xii pages. Illus. 6×9. $17.50.

It was but twelve years ago that Prof. S. K. Mitra, of the University College of Science in Calcutta, published the first comprehensive treatise on the upper atmosphere.[1] This monumental work which, as he put it, took him a solar cycle to complete, has remained without a peer. Mitra regretted his inability to include the results of the first explorations of the upper atmosphere by American workers using V-2 rockets but felt that he could not delay publication any longer. The book was quickly sold out and within five years (1952) was published in a second edition with much material added.

Now there is an avalanche of research focused on the upper atmosphere and Prof. Massey and Dr. Boyd, of the Physics Department at University College in London, have recorded the great advances made during the International Geophysical Year of 1957–1958 and the years just preceding. Their book, however, is not simply an extension of Mitra's work. In the authors' words, it is neither a text nor a monograph. There are no direct references to the literature, although a selected list of twenty items for correlative reading has been included at the end. In a book which is slightly less than half as long as Mitra's, the authors make a good attempt to touch upon every aspect and known phenomenon of the upper atmosphere, treating the most basic with some degree of completeness and making every effort to include the most recent. The treatment has been kept as nonmathematical as possible although, inevitably, it does contain some mathematics, or at least concepts, which are more than elementary. Certainly the authors are to be criticized for not using rationalized MKS units and for using English units frequently.

For the new student of the upper atmosphere, the book is a complete and current introduction though he may wish to consult Mitra's more exhaustive treatment of many subjects and his many references to the literature.

For the advanced student of the upper atmosphere, the clear statements of physical interpretation will be edifying and may clear up more than one point that he has never had the perspective to see.

There are twenty-one half-tone plates and four pages of attractive colored illustrations. The latter show an instrumented rocket nose-cone, three photographs of the aurora, a laboratory discharge in nitrogen, and a laboratory demonstration of the fluorescence of sodium vapor when illuminated by yellow light.

The chapter titles are: 1) The Relevant Physics; 2) The Atmosphere; 3) Research by Balloons and Rockets; 4) Probing with Sound Waves; 5) Probing with Radio Waves; 6) The Ozonosphere and the Ionosphere; 7) Lights in the Night Sky; 8) Aerial Tides and Magnetic Effects; 9) Solar, Magnetic, and Ionospheric Disturbances; 10) Meteors; 11) Cosmic Rays; 12) Artificial Satellites; and 13) Future Possibilities.

The first major international scientific conference concerned with rocket exploration of the upper atmosphere was held at Oxford University in 1953. Some forty-five papers which had been presented at the conference were published the next year under the editorship of Dr. Boyd and M. J. Seaton in consultation with Prof. Massey.[2] Thus the authors of the present volume have been well informed on this new field from the outset and their book undoubtedly makes its most original contribution in this area.

M. G. MORGAN
Thayer School of Engineering
Dartmouth College
Hanover, N. H.

[1] S. K. Mitra, "The Upper Atmosphere," The Asiatic Society, Calcutta, 1947; 2nd ed., 1952 (713 pages).

[2] R. L. F. Boyd and M. J. Seaton, editors (in consultation with H. S. W. Massey), "Rocket Exploration of the Upper Atmosphere," Permagon Press, 1954 (376 pages).

General Circuit Theory, by Gordon Newstead

Published (1959) by John Wiley and Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 140 pages +2 index pages +2 bibliography pages +vii pages. Illus. 4×6½. $3.00.

In this book, the author undertakes to develop "a concise self-contained introduction to the subject of circuit theory from a more or less advanced viewpoint." It is one of the few books available in the area of advanced circuit analysis, and, in general, is well written and contains the latest developments in the theory of linear networks.

The book contains five chapters, and opens with an introduction to the basic definitions of immitance, networks, mesh and node equations, circuit elements, analogy between electrical and mechanical elements, and the concept of transducers. However, it would be desirable to have a proof or physical justification for the number of independent mesh and node equations. Cramer's rule is used in solving mesh and node equations without any comment on the nonsingularity of the mesh and node determinants.

In the second chapter, a number of basic theorems and properties of linear networks are developed; the superposition theorem, Tellegen's theorem (principle of conservation of energy in a linear network), reciprocity theorem, gyrator as a nonreciprocal element, Thevenin's theorem, and passivity. Each theorem and definition is concisely stated and well illustrated. Thevenin's theorem, however, needs a more detailed investigation of its validity for a network containing dependent sources.

Chapter 3 contains properties of linear passive four-terminal networks, open- and short-circuit parameters, general circuit parameters, interconnection of networks, image parameters, matching problems, reflection and insertion loss, etc.

Chapter 4 is the longest chapter, and it contains Fourier transforms, Heaviside and Dirac functions, the use of the complex frequency plane to develop the impulse response of a network, and properties of network functions for two- and four-terminal networks. The relationship between the real and imaginary parts of a network function, the phase-area theorem, and minimum and nonminimum phase shift networks are illustrated.

Chapter 5 deals with approximation methods in nonlinear problems such as the linearization method, the method of power series or high order approximation, and the switch method.

This reviewer feels that some of the illustrations are too concise, and consequently some of the important mathematical and physical implications are lost. The brevity of presentation may have resulted from the author's noble effort to keep the size of the book small.

Wan H. Kim
Dept. of Elec. Eng.
Columbia Univ.
New York, N. Y.

Experimental Music, by Lejaren A. Hiller, Jr. and Leonard M. Isaacson

Published (1959) by McGraw-Hill Book Co., 330 W. 42 St., N. Y. 36, N. Y. 179 pages+17 appendix pages. Illus. 6×9¼. $6.00.

Most of this book is a description of a sequence of digital computer programs for the composition of music. The programs were developed by the authors and executed on the Illiac computer. A variety of styles was produced, ranging from strict counterpoint to exceedingly dissonant atonal chromatic passages. All works are for string quartet. In some pieces only part of the music, such as pitch or time or dynamics, is specified by the computer; in others all is a computational result.

The essence of the composition program is a random number generator producing a sequence of independent numbers, a mapping from these numbers onto the musical parameter to be selected, and a set of rules for rejecting numbers or sequences not meeting certain requirements. The rules are furthest developed for strict counterpoint and include sequential specifications over a maximum of three notes and harmonic specifications over a maximum of two successive chords. Additional rules could be used to limit the range of a voice and to terminate with a cadence. The development and use of these rules is probably the authors' greatest advance over existing music composing programs.

Samples of the various compositions were combined into one piece, "The Illiac Suite," which lasts for about 15 minutes. A copy of the score is appended to the book. Perhaps the easiest way to appreciate the great significance of the authors' work is by hearing the music. The most impressive feature is that the various styles for which the programs were intended are indeed achieved. The early counterpoint might well have come from a hymn. The unrestricted chromatic passages are reminiscent of von Webern, while the chromatic passages with controlled harmonics occupy an intermediate position and can be compared with Bloch's style. Both the range of styles and the control over style is excellent.

The computer music for short times of 5 to 10 seconds compares well with similar sections of a human product. Over longer times, the computer music tends to seem aimless and thus inferior. If the computer is viewed as an aid to a human composer, then the 10 second time is a measure of achievement in that the composer need only specify the music every 10 seconds. Without the computer, he must specify several notes per second. Thus, the computer has achieved a saving in work of perhaps 40 to one, a saving which is quite substantial.

The most apparent limitation to the computational process is the difficulty of introducing long range correlations in the music, such as repeated themes and developments. Generation with independent random numbers tends to produce uncorrelated results. The authors have tried making successive intervals dependent by use of a Markoff chain. However, much more complex statistical structures must be developed which will allow high correlations between widely separated portions of the music.

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Radio Engineering Handbook, Fifth Edition, edited by Keith Henney, prepared by a staff of specialists

Published (1959) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 1748 pages+27 index pages+ix pages. Illus. 6×9. $25.00.

Any reference manual that has been serving an industry for more than a quarter of a century as a first source when a quick answer to any general problem is needed, does not need much of an introduction by a reviewer. This Fifth Edition has been almost tripled in size and includes seven chapters on new subjects. It seems that all material in the previous edition, which appeared in 1950, has been competently re-examined, and a vast amount of new information has been added, particularly in the fields of solid state device applications, nonlinear circuits, and new tubes, components, and measurements in high frequency applications. The wealth of formulas, tables, circuits and descriptions of systems that have appeared in earlier editions in each branch of radio is still included, augmented by additional items and updated revisions where necessary. There is no hesitency in suggesting that this reference will find frequent use if kept at hand by any engineer. This edition will usually prove worthwhile, even if an earlier one is still at hand.

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Proceedings of the Fourth Conference on Magnetism and Magnetic Materials, sponsored by the Magnetics Subcommittee of the AIEE Committee on Basic Sciences. Supplement to the Journal of Applied Physics, Vol. 30, 1959

Published for the American Institute of Physics by the McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 323 pages+vi pages. Illus. 8×10¾. $10.00.

This book offers, in a single volume, an excellent compendium of recent research and developmental effort in the broad field indicated by the title above. Over 144 papers are included, covering every area of current interest in magnetism. Of special interest to the IRE member are the papers dealing with amplifiers, microwave applications, instrumentation, computer components, and thin films. Although this book will primarily be of interest to those working in the field of magnetism, it is reviewed here since it is such an excellent collection of important papers in a field which is of increasing technological importance.

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Basic Electronics, by Bernard Grob

Published (1959) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 487 pages +10 index pages +3 bibliography pages +21 appendix pages +ix pages. Illus. 6×9. $9.25.

This is an excellent book for an introductory course on electronics. It contains enough material to offer the reader an understanding of the basic principles. Books written on this subject frequently contain too many topics for proper comprehension. Covering only the basics reflects good judgment on the part of the author.

The book includes Ohm's law, series and parallel circuits, meters, magnetism, dc and ac, resistance, inductance, capacitance, plus the basic ideas of electron tubes and transistors. Circuitry and applications of these basic ideas are left to a second volume now in preparation. By including only the basics, the author has been able to give fairly comprehensive treatment of each topic. Items such as the practical use of components, care and maintenance, and basic troubles might have suffered had the complete subject been attempted in one volume. This is illustrated in the chapter on batteries where charging and maintenance are included.

Much of the writing seems to anticipate the reader's questions, which no doubt stems from the author's own experience in teaching the subject. The chapter arrangement is extremely logical and the material within the chapters shows much more than just casual organization. The writing itself is clear and concise, and sufficient pictures and diagrams are included to improve the presentation greatly.

Each chapter begins with an introduction, giving the reader some idea of what to expect. A summary at the end of each chapter emphasizes the main points presented. Self-examination questions for each chapter (with answers in the back of the book) are extremely helpful to all students, particularly to those who will read this without the aid of an instructor. A ready source of information is available through the many appendixes at the end of the book.

This is the first printing, and this book, too, seems to contain its share of minor discrepencies, for example on page 31 the average cost of electricity is listed as 3¢ per kilowatt hour and on page 352 it is 4¢. In the appendix, the FCC assignments are listed from 30 kc instead of 10 kc.

In general, the book is a valuable addition to the electronics field.

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Sampled-Data Control Systems, by John R. Ragazzini and Gene F. Franklin

Published (1958) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 312 pages+5 index pages+5 bibliography pages+8 appendix pages +ix pages. Illus. 6×9. $9.50.

This book presents a lucid and explicit summary of the techniques for analysis and design of sampled-data systems. It opens with an analytical description of the processes of regular sampling of time functions and of the reconstruction of time functions from their samples. The description of the *Z* transform covers the processes of direct and inverse transformation and the initial and final-value theorems. The concept of the transfer function to describe pulsed filters is presented. Next, the application of transfer functions to analyze sampled-data systems is presented and the stability criterion is derived. The next two chapters deal with selection of compensation elements for feedback systems. First, the use of continuous signal compensators is considered; then digital compensators are considered. The fact that the analysis of digital compensators is the more tractable leads to a much simpler and more explicit design procedure for digital compensation than for continuous signal compensation. Several techniques are presented for analysis of the behavior of the continuous output of a sampled-data system between sampling instants. The analysis techniques for sampled data systems with random inputs are presented. Multirate sampled systems are discussed and several applications of sampled-data theory are presented.

The book will be useful both as a text book and as a reference. Its strongest feature is its clear and explicit exposition of various analysis techniques. As a text book, it suffers most from the absence of emphasis on concepts rather than merely on techniques. There is little explicit comparison between the concepts of design of continuous servos and those which would be applicable to sampled-data servos. The reader already familiar with continuous servo design would find little in this book which he could recognize as analogous to what he already knows, beyond the general similarity in techniques.

In many cases, explicit comparisons would have been illuminating. In conventional servos, the effectiveness of the feedback loop is increased with the increases in loop gain that can be accommodated. Generally, the error coefficients provide an effective measure of the servo following capability and its insensitivity to load disturbances. The relevance of these measures of performance of sampled-data servos was not mentioned. From a practical point of view, it would be very valuable to have a simple measure of how often the error must be sampled to provide adequate suppression of load disturbances. While techniques for making such evaluations are presented, the concepts are not pointed out, and they probably would be missed by the uninitiated student. No doubt the authors intended that such concepts be driven home to the student by problems.

On the whole, the book makes a very useful contribution. Its style is clear and specific, the selection of topics is good, and it does a good job of summarizing the work done in the field.

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Electron Physics and Technology, by J. Thomson and E. B. Callick

Published (1959) by the MacMillan Co., 60 Fifth Ave., N. Y. 11, N. Y. 515 pages +11 index pages +xiv pages. 5¾ 8¾. $10.00.

This book, written by Professor J. Thomson of the Royal Naval College, Greenwich, and E. B. Callick, Chief Engineer of the English Electric Valve Company, is intended as an undergraduate engineering textbook on electron tubes and their operation. However, about 10 per cent of the text covers semiconductor device principles and technology, so that the authors have chosen to adopt a broad title, even though this may be a little misleading.

The first of the six major sections covers a general introductory treatment of free and bound electrons, including the principles of electron emission, electron optics, vacuum and gaseous conduction, a short chapter on semicondutors, and a chapter on noise. The next section is entitled Electron Devices Employing Space-Charge Variation, chiefly diodes and grid-controlled tubes; a short chapter on the bipolar transistor is also included, thereby showing that the section title is something less than accurate. The next two sections, on electron inertia effects, and on microwave tubes, comprise about one-third of the book, and they are its best parts. Magnetrons, klystrons, and traveling-wave tubes are explained both in principle and in some detail. The fifth section is on special tubes, and it covers cathode-ray, storage, switching, and photosensitive devices. A final section covers electron tube materials and construction, and includes one short chapter on semiconductor technology.

The shortcoming of the book lies in the cursory and inadequate treatment of solid-state devices. The transistor and many of its offspring are already important devices at low frequencies. Every year new solid-state switching and computing devices are uncovered. At microwaves, one can expect increasing student interest in such things as masers, reactance (parametric) amplification, and ferrite effects. None of these are discussed, and it may be necessary to supplement this text with material on modern solid-state applications to effect better coverage. Unfortunately, suitable references are lacking. In fact, no supplementary references at all are given in the first three sections; those given in the last half of the book are chiefly to books which, since they predate the present volume, are even less likely to provide a desirable breadth of perspective. In defense of the authors, however, this reviewer does not know how a single book could be prepared in reasonable size and yet cover the entire electron device field.

The authors have written their text with a maximum of practical descriptive material and a minimum of complex mathematics, so that it is easily read, even by someone with little mathematical skill. The book is well indexed and will be of help to those who wish to make a quick review of parts of the electron tube field, as well as to the serious student who follows it through from cover to cover.

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Abstracts of IRE Transactions

The following issues of Transactions have recently been published, and are now available from the Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, N. Y. at the following prices. The contents of each issue and, where available, abstracts of technical papers are given below.

Sponsoring Group	Publication	Group Members	IRE Members	Non-Members*
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Production Techniques	PT-5	2.45	3.70	7.35

* Libraries and colleges may purchase copies at IRE Member rates.

Audio

Vol. AU-7, No. 4, July–August, 1959

The Editor's Corner (p. 89)

PGA News (p. 91)

Wide-Stage Stereo—P. W. Klipsch (p. 93)

Stereophonic playback systems are studied to determine the accuracy with which they can reproduce the geometry of the original sound. Sounds were generated in a geometric pattern, recorded, and reproduced over a loudspeaker array. The methods used were similar to those used by Steinberg and Snow in 1933. Using two sound tracks, a derived center playback channel, and corner placement of flanking speakers, geometry plots were made with almost as good accuracy as when observers listened to an actual person speaking at the indicated stations in the geometric array.

Since wide speaker spacing was used, corner placement becomes natural.

An evaluation of corner speaker placement from the tonal standpoint (as contrasted with the geometric) shows that there is a large increase in quality available by taking advantage of the reflections of the floor and walls. It is shown that corner placement of flanking speakers and use of a derived-channel center speaker affords the best reproduction of geometry as well as tonality.

A Study of a Two-Channel Cylindrical Transducer for Use in Stereo Photograph Cartridges—C. P. Germano (p. 96)

An analytical as well as experimental evaluation of the electromechanical equivalent circuit constants of a two-channel flexural-type element is presented. This unit is a hollow cylindrical PZT ceramic structure electroded and polarized to be responsive to two signals perpendicular to each other.

The electromechanical equivalent circuit chosen to represent this element is based on the analogy between mechanical and electrical vibrating systems, and is a modification of the electromechanical circuit proposed by Mason. It is made up of lumped electrical and mechanical parameters in combination with an ideal transformation ratio.

Along with this evaluation, a brief discussion of performance characteristics of an experimental cartridge utilizing this element will be presented.

A Frame Grid Audio Pentode for Stereo Output—J. L. McKain and R. E. Schwab (p. 101)

The development and performance capabilities of a dual pentode using a single cathode, two separate *Framelok* grids and a twin-plate structure contained in one envelope is described. This new pentode, known as Type 6DY7, is a high-performance tube with superior characteristics of uniformity and stability obtained from its unique structure. Such factors as greater uniformity in tube-to-tube characteristics, reduced characteristic spread, and less susceptibility to characteristic deterioration at high dissipations can be obtained.

This dual pentode offers extreme flexibility in application. Three basic configurations are: 1) sections operated separately (single-ended) giving 5 watts of audio power per section; 2) two sections in push-pull, Class AB_I providing up to 20 watts output at less than 3 per cent distortion; and 3) two tubes in push-pull parallel.

A single tube can be used for two stereo output channels, or two tubes can be operated in push-pull for higher power requirements. The same advantages can be used for monophonic audio systems.

The tube, therefore, offers the circuit designer a choice of usage not possible in presently-available tubes and at cost advantages realizable through a reduction in the number of circuit components.

Circuit Theory

Vol. CT-6, No. 3, June, 1959

Applications of Routh's Algorithm to Network-Theory Problems—W. D. Fryer (p. 144)

The well-known Routh's criterion uses a very efficient computational method, or algorithm, that has been found to reduce greatly calculational labor and chances of error in a number of other important applications to circuit theory. Among these applications are finding common factors of polynomials, computing Sturm's functions, synthesizing RC, RL, or LC ladder networks by means of continued-fraction expansions, determining RC, RL, or LC realizability of a given immittance function, and analysis of ladder networks. Methods of handling the first two problems, both in normal and special cases, are given and illustrated.

On the Optimum Performance of Variable and Nonreciprocal Networks—T. Schaug-Pettersen and A. Tonning (p. 150)

Lossless, reciprocal transformations of two-state and nonreciprocal two-ports are discussed. (Two-state networks are networks whose parameters may be switched simultaneously between two different values.) The minimum loss of such networks for various applications are shown to depend upon a single characteristic number which is invariant under the transformations studied. When a two-state or nonreciprocal material is used to realize such a network, there is an upper limit for the value of the characteristic number, and this is defined as a figure of merit for the material.

A Power Theorem on Absolutely Stable Two-Ports—G. E. Sharpe, J. L. Smith, and J. R. W. Smith (p. 159)

The stability criteria of two-ports are briefly reviewed, and the activity of two-ports is then discussed at some length. It is found that the real power available from an absolutely stable two-port for a fixed input excitation and passive load cannot exceed a maximum value. This maximum value is only obtained when the two-port is *unilateral* and has its parameters on the *stability boundary*.

A "figure of merit" for active two-ports can now be defined in terms of "maximum absolutely stable power gain."

Time-Response Characteristics of a System as Determined by its Transfer Function—J. D. Brule (p. 163)

In this paper a study is made of the step and impuse responses of systems whose transfer functions have all their poles on the negative real axis. The effects that real zeros of the transfer function have on the system response are evaluated. One result shows that if the transfer function has n finite zeros, all on the positive real axis, then the step response of the system has exactly n zero crossings. These step-response characteristics are studied further to establish upper and lower bounds on the position of the zero crossing for the case $n=1$, and other bounds on the time functions for the cases $n=0$ and $n=2$.

Flow-Graph Solutions of Linear Algebraic Equations—C. L. Coates, (p. 170)

A weighted, oriented topological structure, denoted by G and called a flow graph, is associated with a set of m equations in n variables, denoted by $KX=0$, such that K is a connection matrix and X a vertex weight matrix of the associated graph. This same set of equations can be written as $A^{-}{}_{-v}\colon C(A^{+})'X=0$ where $A^{-}{}_{-v}\colon$ and A^{+} are negative and positive incidence matrices and where C and X are respectively branch and vertex weight matrices of the graph.

By familiar algebraic procedures, an expression for the weight x_p, of a nonreference vertex of G is obtained as a linear combination of the weights of the reference vertices (vertices with zero negative order) and can be written as $x_p=\sum^{s}{}_{j=1} \zeta_{p,r_j},\ x_{rj}$. To these algebraic results there correspond topological expressions in terms of subgraphs of G for the coefficients, $\zeta_{p,rj}$. A similar correspondence is obtained between the topological operation of deleting a vertex from the flow graph and the algebraic operation of eliminating a variable from the set of equations. These results are derived from the algebraic equations written in terms of the incidence and weight matrices of the graph. They are similar to those given for the familiar Signal-Flow-Graph, although they are more convenient to use, since the topological properties of the flow graph depend only upon the algebraic properties of the set of equations.

A flow graph can be drawn directly from an electric network diagram, and the flow-graph properties, used to obtain a solution of the network equations. Examples of this for two types of feedback networks are shown.

Triode Network Topology—A. W. Keen, (p. 188)

The 0- and 1-cell elements of topology are identified with a single terminal-pair and a two-terminal-pair transmission network, rather than with a single-terminal (or node) and a one-terminal-pair (or branch), respectively, in order to facilitate topological consideration of unilateral transmission networks, as typified by the triode valve. It is shown that even the simplest triode network has a feedback interpretation; in more general networks, several signal transmission loops may be distinguished, including both inverting and noninverting unilateral paths.

Application of Mellin and Hankel Transforms to Networks with Time-Varying Parameters—F. R. Gerardi (p. 197)

Integral transform techniques for solving linear integro-differential equations can provide insight and flexibility in solving physical problems, especially network problems. The type of differential equation which describes the physical system will dictate the transform that should be applied to simplify the solution and this paper deals with two transforms, namely, the Mellin transform and the Hankel transform. The Laplace transform can be used to solve linear constant coefficient differential equations or networks which are represented by this type of equation. A familiarity with this transform is assumed and is not covered in this paper.

Mellin transforms may be applied to networks which yield the Euler-Cauchy differential equation. This transform will simplify the solution of such an equation. A transform table, similar to that type used in Laplace transform theory, is developed and applied to network problems.

Hankel transforms may be applied to networks which yield the Bessel differential equation or variations of this equation. Unlike the Laplace and Mellin transforms, the Hankel transform is symmetric and the transformed variable is a real, rather than a complex variable.

A transform table of both operations and functions is developed and applied to network problems as before. Three methods can be used to establish the table of transform pairs. They can be described as: performing the integral operation, applying the table of operations on known transform pairs, and deriving the Hankel transform from the Laplace transform. With both transforms, the applications are made to problems in analysis, instrumentation, and synthesis.

Image Parameter Square-Frequency Filter Design—D. B. Pike (p. 208)

By homographic or bilinear transformations of the square frequency plane, it is shown that the image propagation behavior of filters of reactive impedances can, on normalization to the bandwidth, be described independently of the relative bandwidth.

A graphical filter design method, similar to the Kosowsky approximation method for filters of narrow relative bandwidth, is hence made available as an accurate method for any relative bandwidth. For relating critical frequencies of lattice impedances to the peaks of infinite attenuation, results combine the simplicity of the Kosowsky (approximate) formulas with complete accuracy for all relative bandwidths. Methods of treating reflection loss are given.

In terms of the transformed square frequency variable, the image propagation behavior of any filter represents a whole class of filters from which, by homographic transformations, individual members may be formed as band-pass, high-pass, low-pass, or all-pass filters.

Maximally-Flat Time Delay Ladders—S. Deutsch (p. 214)

The driving-point impedance for a maximally-flat time delay response is derived. The impedance is synthesized as an infinite low-pass LC ladder that starts with an $\epsilon G/\omega_0$-farad shunt capacitor. The ladder elements rapidly taper toward a capacitance of $2G/\omega_0$ farads and an inductance of $2R/\omega_0$ henries. The impulse and step responses of the impedance are derived as a series of Bessel functions.

A three-terminal maximally-flat time delay transfer impedance is also considered. The conditions for a smoothly-tapering ladder structure are given. The transfer impedance is synthesized as an infinite low-pass LC ladder whose first two shunt capacitors are $32G/(9\omega_0)$ and $\epsilon^3G/(9\omega_0)$ farads, respectively. The impulse and step responses of the transfer impedance are also derived.

On Realizability of a Circuit Matrix—R. B. Ash and W. H. Kim (p. 219)

Methods of testing the realizability of a matrix as the circuit matrix of a linear connected graph are presented. Several theorems pertaining to realizability are derived. A systematic synthesis procedure is illustrated for a restricted class of matrices.

Theoretical Limitations on the Gain-Bandwidth Product of Three-Terminal Networks—J. J. Spilker, Jr. (p. 224)

Wherever parasitic impedances are found shunting the terminals of a network, certain limitations on the electrical behavior of this network can be found. Typically, these parasitic impedances might represent a transistor, vacuum tube, or some other loading effect. In this paper, theoretical limitations are derived for the gain-bandwidth product of passive linear three-terminal networks (not necessarily lossless) used as low-pass filters. An important use of these limitations is in determining the upper bounds on the performance of video amplifiers.

Bode has considered limitations of this type for an important but restricted class of networks where the parasitic elements are purely capacitive, whereas in this paper, limitations are shown for arbitrary parasitic impedances. One important application of this new generality is that limitations can now be established for transistor amplifiers. This development has required the use of a general resistance integral theorem, the derivation of which is given in this paper. Different limitations are indicated for RLC networks and those allowing mutual inductance. Examples are given.

Book Reviews (p. 229)
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PGCT News (p. 236)

Education

VOL. E-2, NO. 3, JUNE, 1959

An Experiment in IRE-Secondary School Cooperation—J. W. Kearney and M. T. Lebenbaum (p. 67)

The Long Island Section of the IRE has attempted to attack the problem of cooperation with the secondary schools in its region in two ways. The first is to supply technical support to the high-school science teacher by direct contact with the student in areas where rapid scientific advances have made specialist knowledge a requirement. The second is towards the provision of a lecture series specifically for the teachers themselves. This paper describes the approach and the results of the first two years of operation of the program.

Advanced Education in Industry—J. D. Cassidy (p. 73)

With few exceptions, companies in the electronics industry sponsor advanced education. They derive many benefits from the sponsorship of these programs, such as keeping their engineering staffs up to date on new technical advances, increasing the staff prestige, and attracting outstanding engineering graduates.

Industry and Education must provide better advanced education in industry if we are to meet the challenges of tomorrow. Certain problems now present will be overcome in the future with better coordination and planning.

Undergraduate Laboratories—Some Comments on Efficient Use of Student's Time—W. J. Fahey (p. 75)

Some sort of reportorial process is necessary for evaluation of undergraduate laboratory work. A variety of methods currently employed are not entirely satisfactory. Ideally, such a process should accomplish its purpose with a minimum expenditure of time and effort and, wherever possible, enhance the educational efficiency of the laboratory. Under certain conditions, verbal communication may be employed to these ends. In addition to more efficient use of time, other results include: more accurate evaluation, increased effectiveness of laboratory problems as teaching devices, and useful training in the use of verbal communication. In other terms, the communication channel between instructor and student may be given greater capacity, less noise, and changed more nearly into a closed loop.

Criteria for the Selection of Engineers for Employment—L. H. Noggle (p. 78)

The demand for greater numbers of technically-trained personnel, along with the scientific sophistication needed to meet tomorrow's need for new technologies, indicate that we must take a new look at our present criteria for the selection of engineers for employment.

Criteria must be more basic than the mere evaluation of personality, grades and interests. This fact suggests the necessity to re-define the present industrial concept of engineering.

1200 Case Studies of Engineering Motivation—G. E. Moore (p. 82)

Ability, motivation, work challenges, and environment—these things set the pattern for a successful engineering career. One company, through a personal approach, is endeavoring to develop a better understanding of these factors in order to assist its young engineers in fulfilling their true potential.

It is expected that this "Personal Follow" program will result, ultimately, in more effective utilization of engineering personnel, furtherance of professional growth and development, and greater technical contributions from these young members of the profession.

Understanding, Mathematics, and Scientific Education—W. L. Kilmer (p. 85)

The purpose of this paper is to state what the author believes is a good way to develop the powers of understanding of talented college science students. After making a careful and somewhat novel distinction between knowledge and understanding, the paper closely defines the main problem in terms of the new interpretation of "understanding." A short discussion follows which concludes that what is needed is more and better schooling in the central ideas of mathematics. At this point, the tenor of the paper is changed and a semi-popular discussion is given on the fundamental type of mathematics the author has in mind. Finally, a proposal is made which is general enough to be adapted to a wide variety of situations.

Dynamics of Engineering Education—Uniformity or Quality—E. Weber (p. 89)

A number of internal and external pressures bear down on engineering colleges today. These include the shortage of experienced manpower, the rapid rate of scientific discoveries requiring absorption in curricula, the increasing college population, competition by industry for faculty members, and the need for additional income for plant expansion and faculty salaries.

Within the body of engineering schools, one faction presses for the scientific reorientation of curricula while another holds to the professional art of design as the principal requirement in engineering colleges.

Despite the traditional assumption that education is distinguished by large moments of inertia and that the time scale is measured in terms of generations, we lack sufficient time in a world of latent chaos. Positive and exciting internal forces must be injected into our dynamic system.

Success in Science or Engineering—A. G. Grasberg (p. 94)

This study tests several hypotheses concerning the effects that family structure has on an individual's personality development and its influence on his success in a science or engineering curriculum. One of the principal ideas tested is that success in college in science or engineering requires that the student develop strong feelings of independence and consequently be free from over-concern with interpersonal relations. Data were gathered on sixty undergraduates at the Massachusetts Institute of Technology. Two groups of thirty students each were selected: one a "successful" group and the other an "unsuccessful" group. Success and lack of success were defined in terms of academic performance. In general, the successful students come from homes in which the power structure and the roles of the parents are more clearly defined, thus allowing these boys to have a stronger identification with their fathers. The successful students are also found to be less concerned with interpersonal relations. The low achievers showed a stronger preference to work with people than did the high achievers.

To explore further the origins of concern with interpersonal relations, two deviate subgroups, one from each sample, were studied in depth: the high achievers who preferred to work with people, and the low achievers who preferred *not* to work with people. In the case of the six low achievers who disdained working with people, there is evidence that strong conflict existed within the famility during their childhood and that these students probably reacted to these painful experiences by resisting further interactions with people. This gave rise in later life to a preference to work with things. Unfortunately, however, these students are not successful in working in abstract areas. The four high achievers who preferred to work with people are shown to have an adequate identification with their fathers, who, however, are perceived as having considerable "expressive" or feminine-role behavior. It appears that the father who is successful in meeting the demands of an occupation, but who also has time to concern himself with the internal workings of the family, is the one that produces sons who have strong achievement drives and also have a desire to work with people. It is curious, however, that although these students are skillful in interpersonal situations and turn out to be the campus leaders, they do not have a warm regard for people.

Preliminary Studies in Automated Teaching—R. F. Mager (p. 104)

Known learning principles cannot be efficiently applied in the traditional classroom environment. To achieve efficient learning it is

necessary to remold the teaching-learning configuration to one in which the state of the art can be applied. Teaching machines provide such a configuration, and have proved to be dramatically effective in teaching a wide variety of subject matters. There is a need for more sophisticated machines with which to research possibilities of automating instruction in the maintenance of complex electronic systems. Engineers can contribute to teaching machine technology through programming of technical content, through design of appropriate hardware, and through support of teaching-automation research.

Industry's Contribution and Needs in Graduate Education—D. F. Kline (p. 108)

The reduction in time between the discovery of new knowledge and its application to fill human needs has demanded rapid sophistication of engineering and science graduates employed by industry. In a very short time an integrated work-graduate study program provides these graduates with education in depth, an introduction to industry and a realistic base upon which to make a career decision. Industry's need is graduate-study opportunity for its employees; its contribution is the integrated work-graduate study program.

Contributors (p. 110)

Microwave Theory and Techniques

Vol. MTT-7, No. 3, July, 1959

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Guest Editorial—H. J. Riblet (p. 307)

Report of Advances in Microwave Theory and Techniques in U.S.A.—1958—R. E. Beam and M. E. Brodwin (p. 308)

Report of Advances in Microwave Theory and Techniques in Great Britain—1958—J. Brown (p. 325)

Report of Advances in Microwave Theory and Techniques in Western Europe—1958—G. Goudet (p. 327)

Report of Advances in Microwave Theory and Techniques in Japan—1958—I. Someya (p. 331)

A Ferrite Cutoff Switch—R. F. Soohoo (p. 332)

The theory and operating characteristics of a new type of high performance reflective switch is given. It utilizes the cutoff phenomenon in transversely-magnetized ferrites. The insertion loss of the device is 0.4 db and over 60 db within the 8.8 to 9.5 kmc band when the ferrite is demagnetized and magnetized respectively. The reflection coefficient of the switch in the "off" state is more than 90 per cent over this same band. In contrast to most other ferrite devices, it is of the reflective rather than the absorptive type. Furthermore, it has the unique property that its operating bandwidth is determined mainly by the magnitude of the applied field. Possible applications of the device in antenna switching and as a tunable cutoff filter will be discussed.

Propagation of Constants of Circular Cylindrical Waveguides Containing Ferrites—H. K. F. Severin (p. 337)

The paper describes some results of a theoretical and experimental investigation of the propagation behavior of circular cylindrical waveguides containing longitudinally magnetized ferrite rods. As long as no concentration of the RF-magnetic field in the ferrite occurs, theoretical expressions for the propagation constants can be given by applying first-order perturbation method. Faraday rotation measurements have been made between 5000 and 7600 mc using commercially available ferrites. Reasonable agreement between theoretical and experimental results has been found for a thin axial ferrite rod in an air-filled guide in both cases of saturated and nonsaturated ferrites. Energy concentration in the ferrite determines the propagation behavior in the partially filled waveguide. This effect can be enhanced by surrounding the ferrite rod with a dielectric tube. For a given rod diameter and permittivity of the tube there is an optimum outer diameter of the tube for which the Faraday-rotation becomes maximum.

Magnified and Squared VSWR Responses for Microwave Reflection Coefficient Measurements—R. W. Beatty (p. 346)

In conventional microwave impedance measuring instruments, the measured ratio of maximum to minimum detector signal level is ideally equal to the voltage standing-wave ratio (VSWR) of the termination. In this paper, it is shown how radically different types of response are obtainable in which the observed ratio may approximately equal the square of the VSWR or may be magnified any desired amount. Theory is given enabling accurate measurements by interesting techniques. Accuracies of 0.1 per cent in VSWR to 2.0 have been achieved using magnified response techniques.

Microwave Reflectometer Techniques—G. F. Engen and R. W. Beatty (p. 351)

A rigorous analysis of the microwave reflectometer is presented for what is believed to be the first time. By means of this analysis, the correct adjustment of auxiliary tuners is described, and the errors resulting from incorrect adjustments are treated in a quantitative manner.

It is shown how the reflectometer technique may be further simplified while preserving the accuracy of measurement. A convenient method of adjusting the auxiliary tuners is described, sources of error are discussed, and an example is given of the calculation of error limits.

Application of a Backward-Wave Amplifier to Microwave Autodyne Reception—J. K. Pulfer (p. 356)

A microwave receiver using a single-circuit backward-wave amplifier as a combination radio-frequency amplifier and homodyne local oscillator is described. The amplifier tube is operated at a value of beam current just above that required to maintain oscillation. It is shown that in this way, the high gain and narrow bandwidth of the single-circuit backward-wave amplifier may be utilized in an electronically tunable microwave receiver. The resultant sensitivity is 10 to 15 db worse than that obtainable from a good superheterodyne. The loss in sensitivity is due entirely to the high noise figure of the backward-wave amplifier, which can theoretically be reduced to a value comparable with that of a superheterodyne. The advantages of the receiver are its simplicity and its lack of image difficulties. Rejection of off-frequency signals is such that they are attenuated by at least 50 db.

Mode Theory of Lossless Periodically Distributed Parametric Amplifiers—K. Kurokawa and J. Hamasaki (p. 360)

In this paper, an operator $T\theta$ is introduced for the analysis of the periodically distributed parametric amplifier. The operator is the product of a diagonal matrix expressing the pumping phase relation and the T matrix of the basic section of the amplifier. The eigenvectors of $T\theta$ are called the "modes" of the amplifier. The orthogonality properties of the modes are proved in a similar way as for the conventional mode theory. Finally, an expression is derived for the power gain of the amplifier as an application of the theory.

Surface Wave Transmission Line Composed of Dielectric Membrane—M. Sugi and T. Nakahara (p. 366)

This paper describes the O-guide and X-guide which are proposed by the authors and are the advanced surface waveguides composed of thin dielectric sheets. The results of an analysis of the TE fundamental mode in the O-guide are described, and the theoretical characteristics as a transmission line are discussed. The practical guides are suitable especially for the SHF region and guides can be obtained which have lower attenuation constants than coaxial lines, G-lines, and rectangular waveguides.

The Transmission of TE_{01} Wave in Helix Waveguides—T. Hosono and S. Kohno (p. 370)

Relations are investigated between the transmission characteristics of a helix waveguide and its surface impedance in regions where any simple approximate formulas are not available because of the magnitude of the surface impedance. The numerical calculations show that, for any given value of the surface impedance and the angular mode index, there exists an infinite number of different modes which are distinguishable from each other by different values of the radial propagation content.

Selecting a mode with minimum attenuation for each given surface impedance, we can draw the equiattenuation lines, connecting these points of equal attenuation on the complex surface impedance plane. At some point on the complex surface impedance plane, a maximum value of the minimum attenuation is found. For the TM_0 mode supported by a helix waveguide 50 mm in diameter, used at a frequency of 50 kmc, this minimax value of the attenuation constant is about 8 neper per meter, and the corresponding value of the surface impedance is about $57.6-j28.8$ ohms. The attenuation constants of all the TM_0 modes corresponding to this optimum value of the surface impedance cannot be smaller than this minimax value.

The same kind of calculations are also performed for the two lowest hybrid modes. Physical structures giving the best value of the surface impedance are also suggested.

Design of Linear Double Tapers in Rectangular Waveguides—R. C. Johnson (p. 374)

This paper considers the problem of a taper connecting two uniform waveguides of arbitrary dimensions and propagating a single mode; an approximate expression for the reflection coefficient is derived. The special case of a linear double taper in rectangular waveguide is examined in detail for propagation in the TE_{10} mode. Approximate expressions for the reflection coefficient and voltage standing wave ratio as functions of the taper dimensions and free space wavelength are derived and experimentally verified.

Spurious Mode Generation in Nonuniform Waveguide—L. Sloymar (p. 379)

This paper deals with the problem of a nonuniform waveguide joining two uniform ones and the spurious modes generated by it when a pure mode is incident in one of the uniform waveguides.

The generalised telegraphist's equations are stated and transformed into a set of differential equations for the amplitudes of the forward and backward travelling waves. The expressions for the coupling coefficients between the various modes are given and analysed.

By making certain assumptions, the differential equations are solved and the amplitudes of the modes are given in a closed form.

Subject to these same assumptions, it is proved that the power in the spurious modes may be kept below any predetermined level, provided the nonuniform waveguide is sufficiently gradual.

A High Power Diplexing Filter—L. Young and J. Owen (p. 384)

An L-band diplexing filter has been constructed with an estimated power-carrying capacity of 5 megw at atmospheric pressure (for a power safety factor of nearly four to one) and an insertion loss of less than 0.1 db.

The filter consists of two hybrid junctions and two high pass waveguide sections, which are arranged as in a balanced duplexer, with the "TR-tubes" replaced by the high-pass sections.

In the upper frequency band, the input VSWR is better than 1.10 over a seven and one-half per cent bandwidth, but deteriorates only slightly over a larger bandwidth. In the lower frequency band, the input VSWR is better than 1.32 over a 13 per cent bandwidth. The separation interval between these two bands is approximately 10 per cent between their nearest frequencies.

Correspondence (p. 388)
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Military Electronics

Vol. MIL-3, No. 3, July, 1959

Guest Editorial—E. C. Callahan (p. 67)

Design Considerations for a Celestial Navigation Trainer—M. D. Bennett and N. B. Mickelson (p. 69)

This paper gives a short history of the need for navigation training and tells what a navigator should know. It also tells how navigators were trained in the middle ages and of training devices used then as well as explaining the requirements of the modern celestial navigation trainer and how the 1A19 meets these requirements. It explains, in general engineering terms, the techniques used for simulation of motion and references and changes in references required for nagivating.

Synthetic Representation of Terrain Features on a Simulated Airborne Radar Display—J. T. Slattery and M. Kamenetsky (p. 75)

This paper traces the development of the various techniques used to generate synthetic land mass or terrain radar signals for radar training devices. The survey begins with a description and assessment of the Ultrasonic System and concludes with a discussion of the more flexible Two-Transparency System now under development by the Navy.

Development of the Frst Helicopter Operational Flight Trainer—E. G. Cairns (p. 82)

This paper describes the design and development problems associated with the construction of the first operational flight trainer to simulate a helicopter. Included is a description of the components comprising the trainer along with a discussion of its capabilities and training value for indoctrinating Army helicopter pilots in the flight characteristics of the H-37A Helicopter. Problems in deriving a complete set of motion equations were encountered in the initial phases of the project. These are described as is the approach used in simulating the rotor aerodynamics. The attachment to the operational flight trainer used by the student for visual flight training is also described in detail.

Simulation of Earth's Topography for Research and Engineering—S. Domeshek (p. 87)

This paper explains the present methods of simulating the earth's topography and their uses, the difficulty and time consumed in making some of these simulations, and the limitations of their uses. It then explains the need for some better method because of the greater volume of topographic information required in greater detail because of the needs of cold war, national defense, industry, road expansion, seaway expansion, airport construction, radar site construction—all to be done in a great hurry. It leads up to the automatic terrain model system. It explains quickly the several systems that were considered and why the printed circuit system was chosen. It mentions the fact that the information is stored on magnetic tape and utilized to carve a three-dimensional terrain model, and then goes into detail as to the greater information that this particular system can provide automatically that cannot be done except through extensive hand calculation with the other systems.

An Integrated Space-Flight Simulator—M. Ackerman (p. 92)

The role of the flight simulator in the space vehicle program is presented in this paper. Application of a simulator as an engineering and development aid is the subject of the discussion. A simulator for training the space crew is anticipated and therefore is mentioned in passing.

A brief review is made of contemporary thinking regarding anticipated physiological and psychological effects on the future crew. A simulator is then defined which will integrate these effects, thus providing a complete environment for experimentation.

Early phasing of the integrated simulator with the space vehicle is suggested as a better foundation for design of the space cabin or capsule than sole dependence on feedback from early flights.

The Human Disorientation Device—A Simulator of Angularly-Accelerated Motion—J. H. Achilich (p. 99)

The Human Disorientation Device has been developed as a research tool in the field of aviation medicine for the generation of angularly accelerated motion to enable the accomplishment of medical research in the field of animal or human responses to angular acceleration.

The device will produce accurately known and controlled values of angular acceleration about two axes of rotation when subject is seated so that his head is located at the point specified by the intersection of the axes.

The Human Disorientation Device will allow medical research in the field of sensory responses to angular acceleration, vertigo, and similar phenomena required for an analysis of human behavior and human performance limitations in the rapid maneuvering (spin and tumbling, etc.) of high-speed aircraft and spacecraft.

A Land-Mass Radar Simulator Incorporating Ground and Contour Mapping and Terrain Avoidance Modes—W. P. Jameson and R. M. Eisenberg (p. 105)

This paper describes a method of simulating the radar displays of an airborne radar system. The simulator employs a scan-programmed vidicon tube and a low-power light source in conjunction with a three-dimensional terrain model to simulate radar return from land-mass formations, cultural areas, and target complexes. All effects of a moving aircraft, including velocity, heading, altitude, position, and attitude, are included in the simulation.

This device will produce the displays for ground mapping, contour mapping and terrain clearance radar systems. It may be employed with an operation flight simulator or as a self-contained radar mission trainer for radar navigation and blind bombing operations.

Thirty-Two Aircraft Radar Track Simulator—L. Packer, M. Raphael, and H. Saks (p. 114)

This paper describes a Radar Track Simulator which generates the track of thirty-two aircraft in x, y, and h coordinates accurate to one-hundreth of a mile and produces video accurate to one-hundreth of a mile in range, one milliradian in azimuth and two milliradians in elevation. The output video signals are modified by the radar beam pattern, aircraft scintillation noise, radar receiver noise, fading of video signal with range, and blip-scan effects to produce a realistic display.

Contributors (p. 123)

Production Techniques

Vol. PT-5, August, 1959

Message from the Editor (p. 3)

Guest Editorials and Biographies of Guest Editors—C. F. Horne (p. 4); E. G. Uhl (p. 6); J. R. Moore (p. 8)

Scanning the Issue—A. R. Gray (p. 11)

Second National Conference of the PGPT, June 4–6, 1959

Modular Dimensioning of Electronic Component Parts for Mechanized Assembly—R. A. Gerhold and W. V. Lane (p. 12)

It is pointed out that certain basic design disciplines are prerequisite to more effective mechanized use of printed wiring. The 25-mil layout grid is described as one of these basic prerequisites. Specification SCL-6225, "Design Requirements for Auto-Sembled Army Signal Electronic Equipment," is presented as a basis for the present recommendations. The concept of "projected component volumes" is introduced to make component-parts dimensions compatible with printed-wiring requirements and to provide both a design guide, and a convenient assessment, for volumetric efficiency. Effects of hole, terminal pad, and conductor-spacing variations are discussed. Component-part height variation is charged with the major contribution to poor volumetric efficiency, and corrective measures are suggested.

Dimensions of length, height, and width are all recommended in building-block steps, compatible with printed wiring of the present, and micro-modules of the future; and certain preferences are given. Specification SCL-6254, "Modular Dimensioning of Electronic Parts," is announced. It is concluded that these recommendations will form a logical extension of the large equipment module to provide greater ease of automation and higher volumetric efficiencies.

Future Component Parts for Mechanization—E. G. Plesser (p. 17)

The author introduces Philco's TV middle-of-the-road philosophy for component parts. Basic ground rules are laid down, such as: machines must be simple and specialized; parts must be uniform and easy to handle. A considerable Philco experience with component insertion is indicated. It is pointed out that "universal" insertion machines are always more costly than specialized capital equipment.

Component parts with a rectangular form factor and special leads are proposed, and the advantages of these parts are listed. The state-of-the-art is considered in order to assess the specific ease of conversion to such modular parts. Modular dimensions for multiple component parts are also suggested. It is emphasized that 60-40 solder coated—not solder plated—parts have always, in Philco's experience, surpassed all other types to some degree. Higher temperatures and shorter time cycles are recommended. The coordinate grid system is briefly discussed from the TV manufacturer's point of view.

It is concluded that the industry has much to gain from a reliable mechanization program, and it is stressed that even the smallest detail is important when tooling for new parts. The rectangular component part is suggested as one solution to those conditions which have yet failed to yield reliable results to the machine designer.

Design Trends in Tomorrow's Capacitors—A. A. Tiezzi (p. 20)

A realistic appraisal is made of present capacitor-design improvements, and of immediately-foreseeable design trends. Three trends are discussed—those toward reliability, low voltage, and automation.

In the area of reliability, accelerated-life and vibration test results are presented, covering 8950 "Hyrel Q" impregnated-paper capacitors. It is pointed out that as the demand for such capacitors increases, the cost differential relative to the garden-variety of sub-miniatures will become very small. It is emphasized that high-reliability tantalum-electrolytic, metallized-paper, and ceramic capacitors will be available in the near future and that the developed processes will "rub off" on other types.

The low-voltage trend is discussed in its

relation to solid-tantalum and other electrolytic types. The new Sprague 109D liquid-electrolyte porous-anode tantalum capacitor is described, and a 2 or 3-to-1 volume-efficiency advantage is shown over previous low-voltage types. Other performance, environmental, and reliability advantages are cited. Improved metallized-paper capacitors are placed in a new niche of reliability; and complex-film types are announced for replacing mica and ceramic types. Life-test data is presented showing a 44-to-1 improvement for one dielectric-film combination.

The automation trend is pictured as toward the molded-paper capacitor, because of its better handling and tolerance qualities. Presently-available more-common types are listed, and some pending improvements are mentioned. Two molded automation types are described.

A new monolythic multi-layer ceramic capacitor is announced which has approximately 70 times the capacity of previous ceramics using 20-mil disks. It is emphasized that the surface has only been scratched in the development of new materials for capacitors. In conclusion, it is pointed out that greater standardization on the part of the electronics industry toward a reduction of types and in stopping the usage of obsolete types will result in better capacitors, and at lower prices.

Research and Development for Man-Machine Systems—G. W. Hoover (p. 23)

The fallacies of present methods of Research and Development are discussed, and it is explained why these methods are being used today. It is posed that research itself needs researching. Inhibited thinking is charged with the predominant responsibility for limited research productiveness. Lack of imagination, fear of ridicule, desire to invent at the exclusion of facts, schedules and resistance to tool changes, and too much reliance on experience—these are given as the most important causes of inhibited thinking. The author warns: not to justify compromises, not to rely on luck, and to stop modifying modifications. Stating the problem in its fundamental terms is illustrated by an interesting story. An analogy to the story is provided by the present complex design of aircraft instrument panels.

A methodology is suggested for conducting research and development by establishing a program of uninhibited thinking—a long-range effort seeking ultimate solutions. Seven basic aims and accomplishments of the program are outlined. Examples are shown where breakthroughs have occurred by using this approach. (Slides were used in the verbal presentation for emphasizing certain points and to show examples of equipment developed from an exemplary program.) It is also pointed out that an interim program can make use of the "rake-offs" from the long-range program.

The "Tuf-Plate Hole" for Printed Wiring (Abstract)—G. B. Geddy (p. 27)

Designing with Polystrip Flat-Wire Cables (Abstract)—A. L. Pugh, Jr. and S. J. Stein (p. 28)

Impact of Transistors on Military Electronics Design (Abstract)—A. B. Jacobson and J. C. Nicholas (p. 28)

Micro-Modules: Component Parts and Material Requirements—S. F. Danko and V. J. Kublin (p. 29)

The growth of our microminiaturization capabilities to date is cited as having been random and uncoordinated. The Signal Corps' micro-module effort is described as a definite step toward a concept that has depth and scope. A new dimension—a ten-to-one size reduction over the best now realized, is selected as reasonably attainable in 3 to 5 years. Named as providing the background for the present program, are such designs as the Army's Korean "Handy-Talkie," the Navy's "Tinkertoy," the Bell Telephone Laboratories' transistor, and the Army's "solder-dipped printed wiring." Also credited as being a major contributor is the recent trend toward "packaging by function" where standard modular dimensions and a throw-away maintenance philosophy buy us another two-to-one size reduction, to reach a plateau of around 50,000 parts per cubic foot.

It is stressed that a positive approach is now needed toward a completely new plateau in size and packaging density, of at least 500,000 parts per cubic foot. Our present capabilities are assessed, and a ten-to-one size reduction is shown for Sprague's ceramic printed circuit, and two transistor amplifiers by Centralab. The Army's micro-module wafer element (0.3 inch $\times$0.3 inch $\times$0.01 inch thick) is announced. A model demonstrating feasibility is shown, where a complete 5-transistor superheterodyne radio receiver is built into an ordinary fountain pen. Present capacilities are displayed for fabricating component parts on the 0.09-square-inch micro element. Specific accomplishments are shown, such as: a precision metal-film resistor, a precision glass capacitor, a flat-plate ceramic capacitor, a hermetically-sealed solid-tantalum electrolyte capacitor, and several other special component parts.

Five categories of Army equipments (portable, vehicular, missile, projectile, and satellite), and three plateaus of temperature (+85°C, +125°C, and +200°C, above a cold level of −55°C) are selected as meeting present Army environmental requirements. The guiding philosophy, in setting up the program, is described as providing: first, a meaningful step forward based on immediately attainable tangible techniques, and second, a parallel solid-state research effort to improve and mature the concept. To accomplish the "big step forward" in size reduction and "throw-away" maintenance, RCA is announced as leader-contractor to coordinate industry-wide activities.

A Punched-Card-Controlled Component-Part Insertion Machine—H. K. Hazel (p. 39)

A new high-speed programmed insertion device for axial-lead component parts is described, which produces the "Y" coordinate motion by movement of the printed wiring board and the "X" and "Z" motion by movements of the insertion head. Although the basic idea is not new, it is claimed that its combination with novel mechanisms has resulted in a truly high-speed experimental programmed machine.

Success of the machine is credited to a new small and lightweight inserting tool, which allows high-velocity movement, using low power, and with reduced resonance. A series of pneumatic cylinders are shown, following the binary progression to provide specific strokes by IBM punched-card control, for both lead preparation and insertion.

Salient features of the mechanism are described as follows: a) almost any part under a diameter of 0.250 inch and a length of 0.850 inch can be handled, b) component parts are center-taped on reels after wrap-around terminals have been added, c) torque sleeves and yokes remove component parts from the tape reels, d) cards are stacked and conveyor fed to the insertion head, e) the controller is in console form, and takes binary-coded cards directly without the need for a decoder, and f) 1920 bits of information are available fron only two cards.

Factors which have been experienced in connection with the manufacture of Sage Computers at IBM Kingston are mentioned. It is claimed that for over two million insertions, most failures have been eliminated, even though insertion is at the average rate of 60 per minute. Potential of the system is estimated at a maintained speed of at least 120 per minute, with its future hinted by the insertion speed of less than 0.1 second which has been attained. Possible utilization of the equipment for other purposes is stressed, such as for programmed drilling.

Evolution of a System for the Production of Electronics Equipment—Mechanization of all Lot Sizes—C. P. Cardani (p. 42)

It is reported that as of last year, an estimated 627,000,000 component parts have been mechanically assembled into 26,000,000 printed wiring boards. It is stated that the production equipment requirements and desires of the various assemblers of electronics equipment vary from a single bench-mounted inserting machine (for small lots), to the punched-card-controlled automatic-assembly machine, or even the automatic conveyor. It is pointed out that there is no one piece of equipment that will satisfy the needs of all assemblers, but that the DYNASERT system described can satisfy most.

The paper includes a discussion of: a) factors governing the choice of a system, b) development of the DYNASERT machine system, including machines for component-part preparation, insertion—4 types, and conveying—up to 48 stations, c) varying the system to meet changing production demands, d) considerations affecting design for mechanical assembly, and e) benefits of mechanized assembly.

An account is given of five users, making from 20 to 7000 panels per day, where all showed a considerable saving through mechanization.

Microminiaturization Techniques (Abstract)—J. Finklestein (p. 50)

New Techniques in Plotting, Encapsulating, and Small Parts Molding (Abstract)—J. L. Hull (p. 50)

Automation of Single-Axis Floated-Gyro Drift Measurement—J. G. Nelson (p. 51)

This paper describes the technique and equipment developed for automating measurement of the drift rate of precision single-axis floated gyros. The basic construction principles of single-axis floated gyros are described and illustrated. The sources and components of drift are then discussed and defined. The random component of drift is shown to be a useful measure of gyro quality and is, by reason of its definition, suited to automatic testing techniques.

The equipment used to measure the random component of drift consists basically of a single-axis servo table (in which the gyro to be tested is mounted), the servo table and gyro operating circuitry, and the programming and readout devices. Although adaptable to a variety of situations, the equipment is designed specifically to applying the "cogging" or repositioning type of single-axis gyro-drift test. The servo table is slaved to the gyro output so that the table angular rate is equal to gyro input plus gyro total drift.

Two microsyns (rotary differential transformers) are attached to the table shaft with their null positions spaced at an accurately known angle. The unique phase characteristic of the microsyns is used to gate a precision frequency to a time-interval meter and a digital recorder. With a component of Earth Rate as input to the gyro, the time required for the servo table (and gyro) to process through the accurately-known angle is measured a number of times. The standard deviations of the average rates through the angle is taken as random drift.

The time data is printed out in digital form for transfer to punched cards and digital processing. The application of the equipment to the development and production testing of precision single-axis floated gyros provides a means of accumulating large quantities of precise data in a relatively short period of time for a reliable statistical measure of gyro-production quality.

Abstracts and References

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NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these papers, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

The Index to the Abstracts and References published in the PROC. IRE from February, 1958 through January, 1959 is published by the PROC. IRE, May, 1959, Part II. It is also published by *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, and included in the March, 1959 issue of that journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

ACOUSTICS AND AUDIO FREQUENCIES

534.001.5(51) **2808**
Acoustics in China—Ma Da-Yu. (*Akust. Z.*, vol. 4, pp. 373–375; October/December, 1958.) Outline of the development of research in China since 1949, in the fields of ultrasonics, architectural acoustics, electroacoustics, speech, musical acoustics and hearing.

534.213.4 **2809**
Attenuation of Plane Sound Waves of Finite Amplitude in Gases—B. F. Podoshevnikov and B. D. Tartakovskiĭ. (*Akust. Z.*, vol. 4, pp. 369–371; October/December, 1958.) Investigation of the dependence of attenuation on sound intensity. A graph shows the distribution of sound pressure in a resonant aluminium tube at a frequency of 13 kc.

534.22-8-14 **2810**
The Propagation of Sound in Seawater—A. V. J. Martin. (*Ann. Géophys.*, 1957, vol. 13, pp. 307–309; October/December, 1957.) A brief description of laboratory experiments using an ultrasonic pulse technique to determine the velocity of sound in pure and salt water. See 1 of January.

534.22-8-14 **2811**
The Velocity of Ultrasound in Water near the Freezing Point—N. F. Otpushchennikov. (*Akust. Z.*, vol. 4, pp. 376–369; October/December, 1958.) Brief description of measurements made in distilled water at a frequency of 0.7 mc in the temperature range +20° to 0°C. Results indicate a velocity minimum at 0.7°C. and a maximum adiabatic compression at +2°C.

534.232-8-14:537.228.2 **2812**
Electrostrictive Generation of Ultrasonics in Liquids—E. Gerdes. (*Naturwiss.*, vol. 45, pp. 280–281; June, 1958.) Preliminary report on measurements to determine the magnitude of electrode deformation due to Coulomb attraction. See *e.g.* 310 of 1956 (Goetz).

534.26 **2813**
Diffraction of Sound Waves in Converging Beams—B. D. Tartakovskiĭ. (*Akust. Z.*, vol. 4, pp. 355–360; October/December, 1958.) Approximate formulas are derived for the sound field near the focal point of a converging beam, characterized by a nonuniform amplitude distribution over the wave front and spherical aberration.

534.522.1 **2814**
Measurements of Finite Amplitude Distortion of Progressive Ultrasonic Waves at Moderate Intensities—K. L. Zankel and E. A. Hiedemann. (*Naturwiss.*, vol. 45, pp. 329–330; July, 1958. In English.) Low-amplitude waves were investigated by measurements in water at 2 and 4 mc, and in carbon tetrachloride at 2 and 3 mc over a range of pressures and at various distances from the transducer.

534.614-8 **2815**
Measurement of Ultrasonic Wave Velocities and Elastic Moduli for Small Solid Specimens at High Temperatures—H. J. McSkimin (*J. Acoust. Soc. Am.*, vol. 31, pp. 287–295; March, 1959.) Data for fused silica and single-crystal Ge are listed for temperatures up to 300°C in illustration of the measurement methods described.

534.614-8-14 **2816**
Modification of Ultrasonic Interferometer Design—A. A. Isaev, I. G. Mikhaĭlov and A. S. Khimunin. (*Akust. Z.*, vol. 4, pp. 363–364; October/December, 1958.) Note on the design of an improved quartz oscillator for use in interferometric measurements of sound velocity in liquids.

534.75 **2817**
Unpleasantness of Distorted Sounds: A Criterion Derived from the Distortion Spectrum—E. R. Wigan. (*Nature, London*, vol. 183, p. 1320; May 9, 1959.) An objective criterion of "unpleasantness" has been computed. Methods for checking its validity are briefly discussed.

534.76:534.85 **2818**
Moving-Magnetic Stereo—H. Horowitz. (*Audio Eng.*, vol. 43, pp. 19–21, 47; May, 1959.) A description of a pickup in which the stylus lever is attached to a magnet pivoted between the pole faces of two pairs of pickup coils Characteristics are discussed.

534.78:621.39 **2819**
Intelligibility Evaluation of Voice Communications—H. Schwarzlander. (*Electronics*, vol. 32, pp. 88–91; May 29, 1959.) The integral of a difference voltage due to the pure speech signal and that passed through the system under test is used as a measure of intelligibility.

534.781:621.374.33 **2820**
An Electronic Speech Sampler for Studying the Effect of Sample Duration on Articulation—R. Fatehchand and R. Ahmed. (*J. Inst. Telecommun. Engrs., India*, vol. 5, pp. 86–88; March, 1959.) The start of any word is signalled by a pulse which itself operates the subsequent electronic delay and gate.

534.845 **2821**
Panel Absorbents for Low-Frequency Sound Absorption—N. K. D. Choudhury and M. V. S. S. K. Rao. (*J. Inst. Telecommun. Engrs., India*, vol. 5, pp. 103–108; March, 1959.) Resonant plywood panels show effective absorption in the range 75–300 cps.

534.861:534.84 **2822**
The Acoustic Design of Talks Studios and Listening Rooms—C. L. S. Gilford. (*Proc. IEE*, Part B, vol. 106, pp. 245–256; May, 1959. Discussion, pp. 256–258.)

621.395.623.7.001.4 **2823**
The Impedance and Phase Angle of Loudspeaker Loads—R. E. Cooke. (*Muirhead Tech.*, vol. 13, pp. 11–16; April, 1959.) A description of the basic measurement circuit and a discussion of the impedance and phase angle characteristics obtained for moving-coil and electrostatic loudspeaker systems.

621.395.623.8 **2824**
Column Loudspeakers for Public-Address Systems—M. L. Gayford. (*Electronics*, vol. 32, pp. 64–65; June 12, 1959.) The principles of design are briefly described, with particular reference to polar response.

621.395.625.3 **2825**
A Regulator of Speed and Pitch for Sound Recordings—A. M. Springer. (*Electron. Rundschau*, vol. 12, pp. 275–276; August, 1958.) An adaptor unit for magnetic-tape recorders is described. This has a rotating assembly of four magnetic heads to provide independent changes of speed and pitch in recordings.

ANTENNAS AND TRANSMISSION LINES

621.372.8 2826

The Design and Testing of Integrally Constructed Waveguide Assemblies—G. Craven and V. H. Knight. (*Proc. IEE*, Part B, vol. 106, no. 27, pp. 321–334.) A microwave-link repeater is described as an example of an assembly. Testing facilities include a plug-in reflectometer and a swept-frequency reflection display.

621.372.8:537.226 2827

Dielectric Image Lines—S. P. Schlesinger and D. D. King. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 291–299; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

621.372.821 2828

Measurement of the Properties of a Strip Line and its Transition Junction—F. Norman. (*Proc. IRE, Australia*, vol. 19, pp. 788–795; December, 1958.) Measurements made in the range 8–11 cmλ indicate that a single modified TEM mode could be excited efficiently by means of a simple transition junction.

621.372.823 2829

The Waveguide for Low-Loss Transmission—K. Noda, A. Konose, T. Fujii and K. Miyauchi. (*Rep. Elect. Commun. Lab., Japan*, vol. 6, pp. 394–400; October, 1958.) A report of measurements of attenuation in straight circular waveguides, and in serpentine and uniform bends propagating the H_{01} mode in circular and elliptic waveguides.

621.372.826 2830

Launching Efficiency of Wires and Slots for a Dielectric Rod Waveguide—R. H. DuHamel and J. W. Duncan. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 277–284; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

621.372.832.43 2831

Centre-Excited $TE_{10}^{\square} - TE^{\circ}_{01}$ Mode Transducer—B. Oguchi and K. Yamaguchi. (*Rep. Elect. Commun. Lab., Japan*, vol. 6, pp. 389–393; October, 1958.) Experimental data are given on the design and performance of a new type of mode transducer for use in the 24-kmc band.

621.372.832.8 2832

X Circulator—S. Yoshida. (PROC. IRE, vol. 47, p. 1150; June, 1959.) A new four-port waveguide circulator; experimental results are given.

621.372.837.2 2833

A New Form of High-Power Microwave Duplexer—P. D. Lomer and R. M. O'Brien. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 264–267; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1776; October, 1958.)

621.372.837.3:621.318.134 2834

A Fast Ferrite Switch for Use at 70 kmc/s—E. H. Turner. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 300–303; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

621.372.837.3:621.396.65 2835

A Faraday-Rotation Switch for the TH System—J. A. Weiss. (*Bell Lab. Rec.*, vol. 37, pp. 139–143; April, 1959.) Description of a rapid-acting microwave switch based on the Faraday effect, designed for switching standby oscillators into service.

621.372.852.22 2836

A Perturbation Method for Circular Waveguides containing Ferrites—P. J. B. Clarricoats. (*Proc. IEE*, Part B, vol. 106, pp. 335–340; May, 1959.) The propagation coefficient of a guide containing a longitudinally magnetized ferrite is derived. Good agreement is obtained with experimental data.

621.372.852.22 2837

A Phenomenological Theory of the Reggia-Spencer Phase Shifter—J. A. Weiss. (PROC. IRE, vol. 47, pp. 1130–1137; June, 1959.) Explains the essential properties of the device by means of a simplified model. See 387 of 1958 (Reggia and Spencer).

621.372.852.22 2838

Theory of the Mode Spectra of Cylindrical Waveguides Containing Gyromagnetic Media—R. A. Waldron. (*J. Brit. IRE*, vol. 19, pp. 347–356; June, 1959.) The cutoff equations are derived and solved for the dielectric-centered case and the normal modes are studied. The relations between this case and that of the ferrite-centered case studied previously (341 of February) are pointed out.

621.372.852.323:621.318.134 2839

Theoretical Analysis of the Operation of the Field-Displacement Ferrite Isolator—K. J. Button. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 303–308; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

621.396.67.095 2840

Four-Dimensional Electromagnetic Radiators—H. E. Shanks and R. W. Bickmore. (*Can. J. Phys.*, vol. 37, pp. 263–275; March, 1959.) The effect of modulating one or more parameters of an antenna or antenna array, such as aperture dimensions, frequency or phase distribution, is discussed, and applications to multipattern operation, simultaneous scanning and sidelobe suppression are considered.

621.396.67.095:537.311.5 2841

Determination of a Current Distribution over a Cone Surface which will Produce a Prescribed Pattern—H. Unz. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 182–186; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.674.31 2842

The Effects of the Physical Parameters on the Bandwidth of a Folded Dipole—J. F. German and F. E. Brooks, Jr. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 186–190; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.674.33 2843

The Characteristic Impedance of Two Infinite Cones of Arbitrating Cross-Section—R. L. Carrel. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 197–201; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.677:523.164:621.318.47 2844

A Compact Antenna Switch for Scintillation Measurements—W. D. Ryan. (PROC. IRE, vol. 47, p. 1159; June, 1959.) This switch introduces a phase shift of 90° successively into the lines from each of two antennas.

621.396.677.029.63 2845

The Performance of Directive Aerials in Complex U.H.F. Fields—J. A. Saxton and B. N. Harden. (*Proc. IEE*, Part B, vol.106, pp. 315–217; May, 1959.) Apparent gains of directive antennas, relative to a halfwave dipole, were measured at 580 and 904 mc on a number of urban and rural sites. The median gains were similar to the calculated plane-wave gains, but the apparent gain was low, owing to the complexity of the field, on a significant number of sites.

621.396.677.3:523.164.32 2846

A New High-Resolution Interferometer for Solar Studies—Kundu. (See 2936.)

621.396.677.3:621.396.964 2847

A Note on the Effective Aperture of Electrically Scanned Arrays—R. W. Bickmore. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 194–196; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.677.32 2848

The Radiation Characteristics of a Zig-Zag Antenna—D. L. Sengupta. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 191–194; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.677.71 2849

Design Data for Small Annular Slot Antennas—W. A. Cumming and M. Cormier. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 210–211; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.677.75 2850

Hemi-Isotropic Radiators for the *S*- or *X*-Band—E. G. A. Goodall. (*Proc. IEE*, Part B, vol. 106, pp. 318–320; May, 1959.) "An aerial having approximate hemi-isotropic properties has been constructed on the principle that a dielectric rod will act as a guiding medium for electromagnetic energy. Using this principle, a broad-band, shaped dielectric element has been developed, which, when placed at the aperture of an open-ended circular waveguide, radiates with hemi-isotropic cover over a 20 per cent frequency band."

621.396.677.81:621.397.7 2851

The Passive TV Relay and its Practical Possibilities—R. Aschden. (*TSF et TV*, vol. 33, pp. 329–330; November, 1957.) Field strength and antenna gain calculations for typical passive relay systems comprising a coupled receiving and transmitting antenna are given. See also 2852 below.

621.396.677.83 2852

Passive Relay by Microwave Mirror—R. Aschen. (*TSF et TV*, vol. 33, pp. 5–7; January, 1958.) Formulas are given for calculating the mirror area and reflection losses for a typical relay circuit based on a received field strength of 2 mv/m at a frequency of 200 mc.

621.396.677.83 2853

A Log-Periodic Reflector Feed—D. E. Isbell. (PROC. IRE; vol. 47, pp. 1152–1153; June, 1959.) An antenna of the log-periodic reflector type has been constructed which has been used over the range 105–430 mc. Its effective aperture is fairly constant below 325 mc.

621.396.677.85 2854

Microwave Stepped-Index Luneberg Lenses—G. D. M. Peeler and H. P. Coleman. (TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 202–297; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1439; July, 1958.)

AUTOMATIC COMPUTERS

681.142 2855

The Design of a Standard Block for a Digital Computing System—R. J. Miles. (*Mullard Tech. Commun.*, vol. 4, pp. 222–248; April, 1959.) Logical theory, design considerations and practical circuit of a block based on alloy-junction transistors operating at frequencies up to 1 mc.

681.142 2856
Binary Multiplication in Digital Computers—A. Green. (PROC. IRE, vol. 47, pp. 1159–1160; June, 1959.) Shows how many steps can be eliminated from the usual process of multiplication by computer.

681.142 2857
Computation of Sin N; Cos N and mN using an Electronic Computer—E. G. Kogbetliantz. (*IBM J. Res. & Dev.*, vol. 3, pp. 147–152; April, 1959.)

681.142 2858
Rotating-Disk Function Generator for Analogue Computers—M. E. Young, W. M. Alexander and H. D. Schwetman. (*Rev. Sci. Instr.*, vol. 30, pp. 318–322; May, 1959.) A variable-radius revolving lamina modulates the light incident upon the cathode of a photomultiplier tube to produce a required voltage time function.

681.142:518.4 2859
A Design for an Automatic Graph Plotter—M. P. Atkinson, W. T. Bane and D. L. A. Barber. (*Proc. IEE*, Part B, vol. 106, pp. 299–306; May, 1959.) Transistors and printed circuits are used in equipment based on digital techniques. Points may be plotted at a rate of three per second, with an accuracy within 0.01 inch.

681.142:621.318.042 2860
Magnetic-Core Matrices for Logical Functions—A. L. Freedman. (*Electronic Engrg.*, vol. 31, pp. 358–361; June, 1959.) Some applications of cores having a square hysteresis loop.

681.142:621.318.57 2861
The Design of Biased-Diode Function Generators—C. C. Ritchie and R. W. Young. (*Electronic Engrg.*, vol. 31, pp. 347–351; June, 1959.) Relations between the number and spacing of diode sections to give minimum error are derived.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049.7 2862
Recent Advances in Potted and Printed Circuits—H. G. Manfield (*J. Brit. IRE*, vol. 19, pp. 289–302; May, 1959.) "The various potting resins are described in relation to the variation of properties with different proportions of hardener and the effects on the parameters of the potted components. The causes of failure of potted circuits are discussed. Design problems in the use of printed circuits are examined with particular reference to questions of conductor thickness and spacing. A method of sealing printed circuits by a thin polysulphide rubber layer which is sprayed or brushed on is described."

621.3.049.7:621.385.1 2863
Thermionic Integrated-Micromodules—J. E. Beggs, W. Grattidge, P. J. Molenda, A. P. Haase and A. F. Dickerson. (*Electronics*, vol. 32, pp. 80, 83; May 15, 1959.) The construction and application of microminiature heaterless tubes, resistors and capacitors using titanium and ceramic mater als are described.

621.318.57:537.227 2864
The Transpolarizer: an Electrostatically Controlled Circuit Impedance with Stored Setting—C. F. Pulvari. (PROC. IRE, vol. 47, pp. 1117–1123; June, 1959.) The device operates by the controlled transfer of polarization through two or more ferroelectric dielectric sections in series.

621.318.57:621–52 2865
An Electronic Timer with Voltage Control of Setting—R. Gladstone. (*Electronic Engrg.*, vol. 31, pp. 362–363; June, 1959.) A new grid-controlled "bootstrap" circuit with common-cathode trigger provides accurately controlled time delays up to about 100 seconds.

621.318.57:621.314.63 2866
Microwave Switching by Crystal Diodes—M. R. Millet. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 284–290; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

621.319.4:621.3.049.75 2867
Tantalum Printed Capacitors—R. W. Berry and D. J. Sloan. (PROC. IRE, vol. 47, pp. 1070–1075; June, 1959.) Description of the structural features and characteristics of capacitors using sputtered Ta films as the base for the anodized oxide film, with evaporated metal counter-electrodes.

621.319.45:669.718.5 2868
The Surface Enlargement of Aluminium for Electrolytic Capacitors—P. Werner. (*Nachrichtentech Z.*, vol. 8, pp. 269–277; June, 1958.) Various chemical and electrochemical methods are described and compared, and details are given of a method of measuring the increase in surface area achieved.

621.372.5 2869
General Solution of the Symmetric Iterative Analysis of Asymmetric Passive Linear Quadripoles—S. Mayr. (*Arch. Elektrotech.*, vol. 44, pp. 120–129; December 8, 1958.) The asymmetric quadripole is divided into two symmetric quadripole sections which can be treated by iterative matrix methods.

621.372.57:621.3.087.4:551.594.6 2870
Investigation of an Apparatus for Recording Atmospherics—R. Benoit and J. Kernevez. (*Ann. Géophys.*, vol. 13, pp. 321–234; October/December, 1957.) An analysis of an integrating circuit with a long time constant and its response to a series of pulses.

621.372.6 2871
A Topological Nonreciprocal Network Element—A. W. Keen. (PROC. IRE, vol. 47, pp. 1148–1150; June, 1959.) The element is a three-terminal device which may be used with physical elements (immittances) to model the more complex nonreciprocal devices.

621.372.6 2872
Traditors, a New Class of Non-energic Nonlinear Network Elements—S. Duinker. (*Philips Res. Rep.*, vol. 14, pp. 29–51; February, 1959.) From an analysis based on the Lagrangian dynamical equations, a class of nonlinear multiport elements is defined, which are characterized by the property of neither dissipating nor storing but only transferring energy.

621.372.632:621.314.63 2873
Transmitting Frequency Converter in which Gold- or Silver-Bonded Diode is Used—Kita, Sanpei and Okajima. (See 3145.)

621.372.632.029.6 2874
One Aspect of Minimum-Noise-Figure Microwave Mixer Design—S. M. Bergmann. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 424–326; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

621.373:537.312.62 2875
A Cryogenic Oscillator—G. B. Rosenberger. (*IBM J. Res. & Dev.*, vol. 3, pp. 189–190; April, 1959.) A relaxation process based on the transition between the superconducting and conducting phases of a Pb film is described. Oscillations at frequencies around 100 kc have been obtained.

621.373.42.029.422 2876
A Sine-Wave Generator with Periods of Hours—G. Klein and J. M. den Hertog. (*Electronic Engrg.*, vol. 31, pp. 320–325; June, 1959.) An "inverse function generator" based on the difference amplifier [see, *e.g.*, 362 of 1956 (Klein)] is examined and examples of its use are considered 1) in a logarithmic voltmeter, and 2) for sine-triangle waveform transformation. Triangle-sine transformation can be achieved by negative feedback; a VLF triangular waveform obtained from a cathode-ray circuit and relay is thus converted to an accurate sine wave without transients.

621.373.43:621.314.7:621.385.1 2877
Tube-Transistor Hybrids Provide Design Economy—G. A. Dunn and N. C. Hekimian. (*Electronics*, vol. 32, pp. 78–70; June 5, 1959.) A bistable cathode follower and four-stage ring counter are described. The transistors appear in the cathode circuits of the valves.

621.373.52 2878
Physical Principles of Avalanche Transistor Pulse Circuits—D. J. Hamilton, J. F. Gibbons and W. Shockley. (PROC. IRE, vol. 47, pp. 1102–1108; June, 1959.) "A model for the transistor is defined in terms of charge variables and the physical parameters of the device. The transient performance of the model is calculated by focusing attention on the minority carrier charge stored in the base region and the influence of basewidth modulation upon this stored charge. In the charge formulation of the problem, the physical details of the avalanche multiplication process need not be considered; multiplication is accounted for by the boundary conditions which it imposes upon the stored charge. Good agreement has been obtained between calculated and experimentally observed data for a simple avalanche transistor relaxation oscillator."

621.374.3:621.387.4 2879
Time to Pulse-Height Converter—J. V. Kane. (*Rev. Sci. Instr.*, vol. 30, pp. 374–375; May, 1959.) A circuit is described for deriving pulses, the amplitudes of which decrease linearly with time.

621.374.3:621.387.4 2880
Linear Gate of 20-mμs Duration—E. L. Garwin. (*Rev. Sci. Instr.*, vol. 30, pp. 373–374; May, 1959.) Diodes with a 6-mμsec recovery time are used in a coincidence circuit.

621.374.5:538.652 2881
A Torsional Magnetostrictive Delay Line—A. Rothbart. (PROC. IRE, vol. 47, pp. 1153–1154; June, 1959.) An application of the Wiedemann effect, using toroidal coil transducers.

621.375.018.75:537.311.33 2882
Pulse Amplification using Impact Ionization in Germanium—M. C. Steele, L. Pensak and R. D. Gold. (PROC. IRE, vol. 47, pp. 1109–1117; June, 1959.) Some aspects of the phenomena of impact ionization in an impurity-doped semiconductor at 4.2°K are described. Control of the breakdown process is used to obtain pulse amplification in the millimicrosecond range, using two- and three-terminal devices.

621.375.2.029.3 2883
Reducing Distortion in Class-B Amplifiers—B. Sklar. (*Electronics*, vol. 32, pp. 54–56; May 22, 1959.) Linearization is accomplished by a nonlinear compensation network containing diodes. The calculations for an AF amplifier with 2.6 per cent distortion are described.

621.375.232.4 2884
Grounded-Grid Power Amplifier Design—J. L. Dautremont, Jr. (*Electronic Equip. Engrg.*, vol. 6, pp. 33–36, December, 1958.) A graph-

ical design procedure is described, using a disk-seal valve Type 2C39-A as an example.

621.375.4.029.3 2885
Single-Ended Amplifiers for Class-B Operation—H. C. Lin and B. H. White. (*Electronics*, vol. 32, pp. 86–87; May 29, 1959.) A transistorized 10-w high-fidelity push-pull amplifier is described in detail.

621.375.4.029.3 2886
Designing High-Quality A. F. Transistor Amplifiers—R. Minton. (*Electronics*, vol. 32, pp. 60–61; June 12, 1959.) A seven-stage 25-w amplifier is described.

621.375.4.029.3 2887
One-Transistor 'Push-Pull'—J. A. Worcester. (*Electronics*, vol. 32, p. 74; June 12, 1959.) An AF output stage in which the biasing condition is controlled by the rectified output.

621.375.9:538.569.4 2888
Molecular Oscillators and Amplifiers—N. G. Basov and A. M. Prokhorov. (*Priroda*, pp. 24–32; July, 1958.) The principle and operation of molecular-beam oscillators and amplifiers are described with reference to the ammonia-beam maser. Molecular amplifiers based on paramagnetic crystals give a wider pass band and a higher output power than the molecular-beam type. The frequency stability achieved is within one part in 10^9.

621.375.9:538.569.4 2889
Zero-Field Masers—G. S. Bogle and H. F. Symmons. (*Aust. J. Phys.*, vol. 12, pp. 1–20; March, 1959.) "Solid state three-level masers operating with zero magnetic field are shown to be feasible and to have advantages over magnetic field masers in many applications. The requirements of the working substance are discussed and it is found that compounds of Cr^{3+}, Fe^{3+}, Ni^{2+}, and Gd^{3+} should be suitable. Diagrams and tables of maser properties of selected compounds are given; on the basis of present knowledge a number of amplifying frequencies between 120 and 75,000 mc should be available. The range of suitable compounds which has been studied is very small, and should be extended."

621.375.9:538.569.4 2890
Role of Double-Quantum Transitions in Masers—S. Yatsiv. (*Phys. Rev.*, vol. 113, pp. 1538–1544; March 15, 1959.) Conditions are found in which the operation of a three-level maser is governed by the double-quantum process and does not require a true "pumping" stage. Such a case, although realizable in practice, may be of doubtful technical applicability.

621.375.9:538.569.4 2891
Travelling-Wave Solid-State Masers—A. E. Siegman, P. N. Butcher, J. C. Cromack and W. S. C. Chang. (*Proc. IEE*, Part B, vol. 105, supplement no. 11, pp. 711–712; 1958. Discussion.)

621.375.9:538.569.4:123.164 2892
A Maser Amplifier for Radio Astronomy at *X*-Band—J. A. Giordmaine, L. E. Alsop, C. H. Mayer and C. H. Townes. (Proc. IRE, vol. 47, pp. 1062–1069; June, 1959.) "The design and operating characteristics of a maser radiometer for use in radio astronomy at 3-cm wavelength are discussed. The operating system which is described has a bandwidth of 5.5 mc and an input noise temperature, including background radiation into the antenna, of about 85°K. An rms fluctuation level of about 0.04°K is attained using an averaging time of 5 seconds. A discussion of the factors determining the sensitivity of such devices is presented."

621.375.9:538.569.4:538.22 2893
Two-Level Maser Materials—Hoskins. (See 3037.)

621.375.9:538.569.4:538 222 2894
Theory of Three-Level Paramagnetic Masers—P. N. Butcher. (*Proc. IEE*, Part B, vol. 105, supplement no. 11, pp. 684–711; 1958.)
Part 1—Quantum Theory (pp. 684–690).
Part 2—Amplification and Oscillation (pp. 691–698).
Part 3—Output Noise Power Spectrum (pp. 699–704).
Part 4—Noise Figure (pp. 705–709).
Discussion (pp. 709–711).

621.375.9:550.389.2:629.19 2895
Parametric Amplifier Receives Space Signals—(*Electronics*, vol. 32, pp. 80–81; June 5, 1959.) Signal amplification was in *L*-band and pump frequency in *X*-band giving a noise factor of 1 db and bandwidth 100 kc. Using a 32-db paraboloid (diameter 18 feet) the fraction of a watt radiated by Pioneer IV was received at 410,000 miles.

621.375.9:621.3.011.23 2896
Microwave Parametric Amplifiers and Convertors—G. Wade and H. Heffner. (*Proc. IEE*, Part B, vol. 105, supplement no. 11, pp. 677–679; 1958.) The inherent gain, noise and bandwidth characteristics of basic circuits are discussed and a brief description is given of a ladder-network converter in which the output frequency is higher than the pumping frequency.

621.375.9:621.3.011.23 2897
Circuit Conditions for Parametric Amplification—J. E. Pallett. (*J. Electronics Control*, vol. 6, pp. 261–262; March, 1959.) Correction of an error in Valdes' paper (75 of January).

621.376.23 2898
Simplified Product Detector Design—J. L. Ekstrom. (*QST*, vol. 43, p. 43; May, 1959.) A circuit is described for a pentagrid converter which may be self-excited or separately excited and which has an intermodulation balance adjustment to reduce rectification effects.

621.376.4 2899
The Modulator as a Phase Detector—W. Frazer and R. E. Schemel. (*Electronic Engrg.*, vol. 31, pp. 345–346; June, 1959.) A note on the error due to a finite switching voltage applied to a shunt modulator.

GENERAL PHYSICS

535.13 2900
Solution of Maxwell's Equations in Terms of a Spinor Notation: the Direct and Inverse Problem—H. E. Moses. (*Phys. Rev.*, vol. 113, pp. 1670–1679; March 15, 1959.) The use of spinor notation enables the solution to be obtained in more compact form than does vector notation.

537.226 2901
The Quantum Mechanical Theory of the Dielectric Orientation Polarization of Gases: Part 1—The Static Orientation Polarization of a Dipole Gas consisting of Symmetric Spin Molecules—W. Maier and H. K. Wimmel. (*Z. Phys.*, vol. 153, pp. 297–313; December 5, 1958.)

537.311.1:621.396.822 2902
Noise Theory for Hot Electrons—P. J. Price. (*IBM J. Res. & Dev.*, vol. 3, pp. 191–193; April, 1959.) Nyquist's theorem is extended to the case in which the distribution of electrons is disturbed by a steady electric field.

537.311.4 2903
Transient Behaviour of the Ohmic Contact—M. A. Lampert and A. Rose. (*Phys. Rev.*, vol. 113, pp. 1236–1239; March 1, 1959.) The behavior of ohmic injecting contacts is analyzed for transient currents at a fixed voltage. These occur when the free-carrier density in the solid is changed by some exciting agent as in photoconductivity or bombardment-induced conductivity.

537.311.5:538.566 2904
The Calculation of the Field in a Homogeneous Conductor with a Wavy Interface—J. R. Wait. (Proc. IRE, vol. 47, pp. 1155–1156; June, 1959.) Analysis showing that the perturbation of an electromagnetic field in the conductor due to the ripples is proportional to their amplitude.

537.311.5:621.3.015.3 2905
Penetration of Transient Electromagnetic Fields into a Conductor—A. Grumet. (*J. Appl. Phys.*, vol. 30, pp. 682–686; May, 1959.) Theory for a uniform electric field abruptly applied to a plane boundary.

537.322.1 2906
On the Theory of the Peltier Heat Pump—E. S. Rittner. (*J. Appl. Phys.*, vol. 30, pp. 702–707; May, 1959.) The figure of merit for a single-stage pump is optimized in the region of partial Fermi degeneracy.

537.527:537.56 2907
The Space-Charge Field-Emission Hypothesis applied to Hayashi Data on Discharges through Gases—H. Ritow. (*J. Electronics Control*, vol. 6, pp. 236–245; March, 1959.)

537.533 2908
Concerning the Nature of the Aberrations in Electron Sheet Beams—W. E. Waters. (*J. Opt. Soc. Am.*, vol. 49, pp. 304–307; March, 1959.) A power-series expansion is used to derive expressions for the aberrations up to the third order in electron sheet beams subject to purely electrostatic focusing. Four purely geometric aberrations and four aberrations due to chromatic effects are found.

537.542 2909
New Hollow-Cathode Glow Discharge—A. D. White. (*J. Appl. Phys.*, vol. 30, pp. 711–719; May, 1959.) Current densities of 0.5 amp/cm^2 can be obtained with a cathode consisting of a refractory metal with a spherical cavity. In neon, stable characteristics at a few milliamperes are obtained.

537.56:538.56 2910
New Experimental Results for Plasma Electron Oscillations—D. W. Mahaffey. (*J. Electronics Control*, vol. 6, pp. 193–203; March, 1959.) Study of oscillations in low-pressure mercury vapor discharges with plane oxide-coated cathodes.

537.56:538.56 2911
A Lagrangian Formulation of the Boltzmann-Vlasov Equation for Plasmas—F. E. Low. (*Proc. Roy. Soc. A.*, vol. 248, pp. 282–287; November 11, 1958.) A variational principle is found which leads to a new formulation of the problem of small oscillations about equilibrium.

537.581 2912
Wave-Mechanical Correction of the Richardson-Dushman Emission Formula—F. Ollendorff. (*Arch. Elektrotech.*, vol. 44, pp. 177–188; February 12, 1949.) An attempt is made to overcome the discrepancies between the spin-corrected theory of thermionic electron emission and empirical results.

538.1 2913
Bose-Einstein Lattice Gases equivalent to the Heisenberg Model of Ferro-, Antiferro- and Ferri-Magnetism—T. Morita. (*Progr. theoret. Phys.*, Kyoto, vol. 20, pp. 614–624; November, 1958.) A Hamiltonian is presented

that has the form of a finite series of Bose operators and is equivalent to the Heisenberg model. See also *ibid.*, pp. 728–736.

538.3:535.13 **2914**

Formation of Discontinuities in Classical Nonlinear Electrodynamics—M. Lutzky and J. S. Toll. (*Phys. Rev.*, vol. 113, pp. 1649–1652; March 15, 1959.)

538.566 **2915**

Polarization and Angle Dependence of the Reflection Factor of Absorbers for Centimetre Electromagnetic Waves—K. Walther. (*Z. angew. Phys.*, vol. 10, pp. 285–295; June, 1958.) The dependence of the reflection factor on the angle of incidence and plane of polarization of electromagnetic waves is investigated for various types of absorbers and results are confirmed experimentally.

538.566 **2916**

Transients in Conducting Media—P. I. Richards. (IRE Trans. on Antennas and Propagation, vol. AP-6, pp. 178–182; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1439; July, 1958.)

538.566:535.42]+534.26 **2917**

The Effects of Incident Wave Fluctuations on the Mean Intensity Distribution near the Focal Point of a Lens—N. N. Krom and L. A. Chernov. (*Akust. Z.*, vol. 4, pp. 341–347; October/December, 1958.) An extension of Chernov's analysis (3772 of 1958) to the case of fluctuations of arbitrary amplitude.

538.566:535.42 **2918**

The Kirchhoff-Young Theory of the Diffraction of Electromagnetic Waves—O. Laporte and J. Meixner. (*Z. Phys.*, vol. 153, pp. 129–148; November 14, 1959.) A transformation is discussed which facilitates the evaluation of Kirchhoff's double integrals.

538.566:535.43]+534.26 **2919**

On Propagation of Waves in Slightly Rough Ducts—J. C. Samuels. (*J. Acoust. Soc. Am.*, vol. 31, pp. 319–325; March, 1959.) Mathematical treatment of acoustic and electromagnetic wave propagation assuming that the heights of the roughness peaks are small compared to the average separation of the duct walls.

538.566.2 **2920**

The Propagation of a Variable Electromagnetic Field in a Stratified Anisotropic Medium—A. N. Tikhonov. (*Dokl. Ak. Nauk SSSR*, vol. 126, pp. 967–970; June 11, 1949.) Computation of the field on the surface of an anisotropic conducting medium due to a dipole lying in the surface. See also 3036 of 1956 (Tikhonov and Shakhsuvarov.)

538.566.2:548 **2921**

On the Propagation of Electromagnetic Waves in a Medium with Appreciable Spatial Dispersion—V. M. Agranovich and A. A. Rukhadze. (*Zh. eksp. Teor. Viz.*, vol. 35, pp. 982–984; October, 1958.) Brief description of a method more detailed than that of Ginsburg (1169 of April), in which expansions are obtained for "direct" and "inverse," dispersion. It is shown that in cubic crystals inclusion of the spatial dispersion leads to a weak anisotropy of the index of refraction.

538.569.4 **2922**

A General Theory of Magnetic Double Resonance—K. Tomita. (*Prog. Theoret. Phys.*, Kyoto, vol. 20, pp. 743–773; November, 1958.) The theory describes a system consisting of two interacting different species of spin, one being saturated by a strong resonant radiation field and the other being detected by a weak field. See also 95 of January.

538.569.4 **2923**

Multiple-Quantum Transitions in Nuclear Magnetic Resonance—S. Yatsiv. (*Phys. Rev.*, vol. 113, pp. 1522–1537; March 15, 1959.)

538.569.4 **2924**

The Application of Magnetic Resonance to Solid-State Electronics—D. J. E. Ingram. (*J. Brit. IRE*, vol. 19, pp. 357–267; June, 1959.) A description of the basic principles and techniques and an outline of some recent applications.

538.569.4 **2925**

Excitation of Spin Waves in an Antiferromagnet by a Uniform R. F. Field—R. Orbach and P. Pincus. (*Phys. Rev.*, vol. 113, pp. 1213–1215; March 1, 1959.) It is possible to excite spin waves in an antiferromagnet by a uniform RF field provided that spins on the surface of the specimen experience anisotropy interactions different from those acting on spins in the interior.

538.569.4 **2926**

Exchange Effects in Ferromagnetic Resonance—M. A. Gintsburg. (*Zh. Eksp. Teor. Fiz.*, vol. 35, pp. 1047–1049; October, 1958.) A single dispersion law for transverse em waves and for spin waves is derived which takes account of both relativistic and exchange interactions.

538.569.4:538.222 **2927**

Paramagnetic Electron-Resonance Induction—E. Lutze and D. Bösnecker. (*Naturwiss.*, vol. 45, p. 332; July, 1958.) Preliminary note on investigations of induced emission at paramagnetic resonance. $CuSO_4 \cdot 5H_2O$ at room temperature and a wavelength of 3.33 cm were used.

538.569.4:621.318.132 **2928**

Ferrimagnetic Resonance Modes in Spheres—P. C. Fletcher and R. O. Bell. (*J. Appl. Phys.*, vol. 30, pp. 687–698; May, 1959.) The magnetostatic solutions of ferrimagnetic resonance in ferrite spheres are briefly derived. Some experimental results are compared with the theory.

538.569.4:621.375.9 **2929**

Role of Double-Quantum Transitions in Masers—Yatsiv. (See 2890.)

538.652 **2930**

Form Effect in Linear Magnetostriction—H. E. Stauss. (*J. Appl. Phys.*, vol. 30, pp. 698–701; May, 1959.)

539.2 **2931**

Electron Interaction in Solids. Characteristic Energy Loss Spectrum.—P. Nozières and D. Pinse. (*Phys. Rev.*, vol. 113, pp. 1254–1267; March 1, 1959.) The characteristic energy loss spectrum is analyzed with the aid of the dielectric formulation of the many-body problem.

GEOPHYSICAL AND EXTRA-TERRESTRIAL PHENOMENA

523.164:621.396.677.8 **2932**

Improved Measurements of the Positions of 17 Intense Radio Stars—B. Elsmore. (*Mon. Not. R. Astr. Soc.*, vol. 118, no. 6, pp. 603–608; 1958.) Observations have been made at 1.9 mλ, using the Cambridge radio telescope as a crossed-axis interferometer. See also 103 of January (Edge, *et al.*).

523.164.32 **2933**

The Extension of Solar Radio Spectroscopy to Decametre Wavelengths—K. V. Sheridan, G. H. Trent and J. P. Wild. (*Observatory*, vol. 79, pp. 51–53; April, 1959.) Preliminary report on spectrographic investigations in the frequency range 24–40 mc.

523.164.32 **2934**

On Short Periodic Variations in Solar Noise Storms on 200 mc/s—Ø. Hauge. (*Astrophys. Norveg.*, vol. 6, pp. 43–54; January, 1958.) 19 days of enhanced solar radiation on 200 mc in June, July and August, 1955 are investigated by an autocorrelation method in a search for short periodic variations with repetition times between 7.5 and 90 min. Results indicate that some noise storms are characterized by periodic variations with repetition times differing from day to day, while other noise storms exhibit no periodic variations. It is possible that a specific noise storm area retains its characteristics of short periodic variations in radio emission for a solar rotation or longer.

523.164.32 **2935**

On the Fine Structure of Solar Bursts in the 200 Mc/s Range and their Drift in Frequency—Ø. Elgarøy. (*Astrophys. Norveg.*, vol. 6, pp. 55–74; January, 1958.) High-speed records have been obtained simultaneously on 199 mc and 200.5 mc with a twin-channel receiver at the Harestua Solar Observatory during the period February–September, 1957. An analysis of the records shows that 48 per cent of the bursts occur first on the lower frequency, 34 per cent first on the higher frequency and 18 per cent simultaneously. The results are discussed and the receiving equipment is described.

523.164.32:621.396.677.3 **2936**

A New High-Resolution Interferometer for Solar Studies—M. R. Kundu. (*J. Inst. Telecommun. Engrs. India.*, vol. 5, pp. 77–85; March, 1959.) The device is essentially a two-element interferometer with the two antennas in equatorial mounting, which permits use far from the median plane and gives a resolving power of the order of 1′. See 2733 of 1957 (Alon *et al.*).

523.164.4 **2937**

A High-Resolution Survey of the Andromeda Nebula at 408 Mc/s—M. I. Large, D. S. Mathewson and C. G. T. Haslam. (*Nature, London*, vol. 183, pp. 1250–1251; May 2, 1959.) A report of observations made with the Jodrell Bank radio telescope.

523.164.4 **2938**

A High-Resolution Survey of the Coma Cluster of Galaxies at 408 Mc/s—M. I. Large, D. S. Mathewson and C. G. T. Haslam. (*Nature, London*, vol. 183, pp. 1663–1664; June 13, 1959.)

523.164.4:621.396.11:523.755 **2939**

The Scattering of Radio Waves in the Solar Corona—A. Hewish. (*Mon. Not. R. Astr. Soc.*, vol. 118, no. 6, pp. 534–546; 1958.) An account is given of measurements carried out each June over the period 1952–1958 of the radio emission from the Crab nebula at wavelengths of 7.9, 3.7 and 1.9 m. Results indicate a pronounced sunspot-cycle variation in certain regions of the corona, a scatter anisotropy, and the presence of refraction effects in addition to scattering. See also 2286 of 1955.

523.5:621.396.11 **2940**

Theory of the Radio-Echo Meteor Height Distribution in a Non-isothermal Atmosphere—A. A. Weiss. (*Aust. J. Phys.*, vol. 12, pp. 54–64; March, 1959.) The height distribution of echoing points of shower and sporadic meteors belonging to a homogeneous velocity group is calculated for a model atmosphere whose scale height is a linear function of height. Experimental cutoff and the theoretical approximations involved limit the accuracy with which actual scale height and density may be found from observed meteor trails.

523.5:621.396.11 **2941**

Elevation, Height, and Electron Density of Echoing Points of Meteor Trails—A. A. Weiss.

(*Aust. J. Phys.*, vol. 12, pp. 65–76; March, 1959.) These parameters may be evaluated by the continuous operation of ew equipment on 27 mc. At least 60 per cent of all echoes are found to be distorted. The electron density distributions are in qualitative agreement with known meteor mass distributions and trail shapes.

523.745:523.165 2942
Solar Activity and Transient Decreases in Cosmic-Ray Intensity—D. Venkatesan. (*J. geophys. Res.*, vol. 64, pp. 505–520; May, 1959.)

523.753 2943
A New Theory of the Solar Corona—P. J. Kellogg and E. P. Ney. (*Nature, London*, vol. 183, pp. 1297–1301; May 9, 1959.) It is proposed that the solar corona consists of trapped charged particles moving in the magnetic fields of the sun. Experimental data are discussed in terms of this model.

550.385 2944
Disturbances of the Earth's Magnetic Field considered as Relaxation Varietions—P. Herrinck. (*Ann. Géophys.*, vol. 13, pp. 211–221; July–September, 1957.) Records of the horizontal magnetic component at Elisabethville and elsewhere show relaxation processes analogous to post-disturbances of magnetic storms and subject to the 27-day recurrence tendency.

550.385 2945
Possible Causes of Geomagnetic Fluctuations having a 6-sec Period—H. J. Duffus, J. A. Shand and C. Wright. (*Nature, London*, vol. 183, pp. 1479–1480; May 23, 1959.) Comment on 1532 of May (Daniels). Short- and long-period oscillations, sometimes preceding but more often accompanying a main train of magnetic activity are described. They are considered to be associated, and of electromagnetic origin.

550.385.37 2946
Geographical Variations in Geomagnetic Micropulsations—H. J. Duffus, J. A. Shand, C. S. Wright, P. W. Nasmyth and J. A. Jacobs. (*J. geophys. Res.*, vol. 64, pp. 581–583; May, 1959.) Significant differences consistently occur in simultaneous data obtained at stations 25 miles apart.

550.385.37:551.594.5 2947
On a Possible Auroral Origin of Certain Geomagnetic Pulsations—J. Coulomb. (*Ann. Geophys.*, vol. 13, pp. 91–102; April/June, 1957.

550.385.4:523.745 2948
The Relation between the Sudden Disappearance of Filaments and Magnetic Storms—M. Dizer. (*Ann. Géophys.*, vol. 13, p. 325; October/December, 1957.) An analysis of records shows a correlation between the sudden disappearance of filaments close to the sun's central meridian and magnetic disturbances.

550.386:523.755 2949
Green Coronal Line Intensity and Geomagnetism—C. Warwick. (*J. geophys. Res.*, vol. 64, pp. 527–531; May, 1959.) Statistical analysis indicates a minimum in geomagnetic activity following the central meridian passage of regions of high green-line intensity.

550.389.2:629.19 2950
Laws of Motion of an Earth Staellite—Yu. A. Pobedonostsev. (*Priroda*, pp. 19–25; January, 1958.) The principles of multistage rocket flight are considered and formulas for rocket velocity are derived. Tables give the satellite velocity and duration of flight for heights up to 6000 km.

550.389.2:629.19 2951
A Discussion on Observations of the Russian Artificial Earth Satellites and their Analysis—(*Proc. Roy. Soc. A.*, vol. 248, pp. 1–87; October 28, 1958.) The text is given of fifteen papers discussed at a meeting in London, November 29, 1957. These include results obtained using radio telescopes and interferometers, Doppler recorders and direction-finding and field-strength measuring equipment. Applications are made to the computation of orbit parameters. See also 1720 of 1958 for a similar discussion.

550.389.2:629.19 2952
Observations on the U.S.S.R. Earth Satellites and the Study of Radio-Wave Propagation—W. C. Bain and E. D. R. Shearman. (*Proc. IEE*, Part B, vol. 106, pp. 259–263; May, 1959.) Measurements of bearing, angle of elevation and Doppler frequency shift were made at 20 and 40 mc. The observed phenomena could be explained in terms of existing knowledge of ionospheric propagation. The derivation of orbital parameters from the observations is discussed.

550.389.2:629.19 2953
A Type of Variation of the Signal Strength from 1958 δ2 (Sputnik 3)—L. Liszka. (*Nature, London*, vol. 183, pp. 1383–1384; May 16, 1959.) Fluctuations of signal strength relative to the satellite position in orbit indicate that the satellite produces heavily ionized tracks of very long lifetime. Observations have been made to test this hypothesis and results are given.

550.389.2:629.19 2954
Diurnal Lapse of S gnals from Sputnik III—G. H. Munro. (*Nature, London*, vol. 183, p. 1549; May 30, 1959.) A brief note, dated April 28, 1959, states that systematic observations have established that pulse modulation is present only when the satellite 1958 δ2 is in sunlight. On very close transits the CW signal can be detected with sufficient strength to record the Doppler shift.

550.389.2:629.19 2955
Density of the Atmosphere at Heights between 200 km and 400 km from Analysis of Artificial-Satellite Orbits—D. G. King-Hele. (*Nature, London*, vol. 183, pp. 1224–1227; May 2, 1959.)

550.389.2:629.19 2956
Fluctuations in the Brightness of the Second Artificial Earth Satellite—V. P. Tsesevich. (*Priroda*, pp. 78–79; April, 1958.) These brightness fluctuations are explained by the rotation of the satellite on its axis, its maximum brightness corresponding to its greatest cross section as seen by the observer. A graph shows these brightness variations as recorded by the Odessa Observatory.

550.389.2:629.19 2957
The Antipodal Reception of Sputnik III—E. Woyk (Chvojková). (Proc. IRE, vol. 47, p. 1144; June, 1959.) The mechanism of the propagation of waves around the earth within the ionospheric layers is discussed and the best conditions for antipodal reception are deduced. It is concluded that at Stanford, Calif., the best conditions for frequent reception occur from the southeast during summer afternoons. This is in agreement with observations.

550.389.2:629.19 2958
Satellite-Measured Radiation—G. W. Stuart. (*Phys. Rev. Lett.*, vol. 2, pp. 417–418; May 15, 1959.) The relevance of atomic change-processes to the nature of the radiation belt is noted.

550.389.2:629.19 2959
Some Results of Investigations on Cosmic Rays Using Artificial Earth Satellites—L. V. Kurnosova. (*Priroda*, pp. 85–86; June, 1958.) The intensity variations of cosmic rays as recorded during the flight of the second sputnik are shown. There were no appreciable corresponding variations at ground level.

550.389.2:629.19 2960
Corpuscular Radiation and the Acceleration of Artificial Satellites—L. G. Jacchia. (*Nature, London*, vol. 183, pp. 1662–1663; June 13, 1959.) Observations of satellites 1958 β_2 and δ_1 have been re-examined and more accurate values of acceleration have been calculated at twice the original resolution (see 2564 of August). Correlation with 10.7-cm solar radiation is higher for β_2 than δ_1, probably due to greater observational accuracy. An increased acceleration of δ_1 at the time of two major geomagnetic disturbances following flares indicates the effect of corpuscular radiation on atmospheric density at the 200-km level.

550.389.2:629.19:551.510.535 2961
On the Existence of a Strong Magneto-ionic Effect Topside of the *F* Maximum of the Kennelly-Heaviside Layer—P. R. Arendt. (*J. Appl. Phys.*, vol. 30, pp. 793–795; May, 1959.) Observations of the Faraday effect in 108-mc signals from artificial satellites showed noticeable magneto-ionic effects at altitudes up to 2000 km.

550.389.2:629.19:621.379.5 2962
Parametric Amplifier Receives Space Signals—(See 2895.)

550.389.2:629.19:621.396.11 2963
Radio Reflections from Satellite-Produced Ionization—C. R. Roberts, P. H. Kirchner and D. W. Bray. (Proc. IRE, vol. 47, pp. 1156–1157; June, 1959.) Observations have been made on frequencies of 5, 10, 15 and 20 mc and two very different effects obtained on both 10 and 15 mc are described.

550.389.2:629.19:621.398 2964
Cosmic-Ray Instrumentation in the First U. S. Earth Satellite—G. H. Ludwig. (*Rev. Sci. Instr.*, vol. 30, pp. 223–229; April, 1959.) The instrumentation was designed for conservation of electrical power and for stable and reliable operation over a wide range of temperatures.

551.510.535 2965
Some Results of Investigations of the Upper Atmosphere—V. V. Mikhnevich. (*Priroda*, pp. 71–72; May, 1958.) Vertical rocket investigations carried out in U.S.S.R. between 1949 and 1958 showed that, contrary to established opinion, above the *E*-layer there is only a very shallow minimum in electron density. The electron density increases up to 250–300 km with a maximum at 300 km and then slowly decreases so that at 470 km the density is 10^6 electrons per cm^3.

551.510.535 2966
A Theoretical Study of the Dynamical Structure of the Ionosphere—T. Shimazaki. (*J. Radio Res. Labs, Japan*, vol. 6, pp. 109–241; March, 1959.) A comprehensive survey of the modifications to Chapman theory which are necessary to explain the actual behavior of the ionosphere. Both the large F_2-layer anomalies and the smaller ones for the *E* and F_1 layers are discussed. Over 100 references.

551.510.535 2967
Conditions in the Outer Ionosphere—Ya. L. Al'pert. (*Priroda*, pp. 86–87; June, 1958.) It is found that the electron concentration in the outer ionosphere decreases with the height considerably less rapidly than it increases at lower levels. The values obtained

show that at 2000–3000 km the concentrations of electrons and neutral particles are of the order of 10^3–10^2 and 1 per cm^3 respectively.

551.510.535 2968
Investigation of the Equatorial Electrojet by Rocket Magnetometer—L. J. Cahill, Jr. (*J. Geophys. Res.*, vol. 64, pp. 489–503; May, 1959.) Two layers of electrical current were detected, one existing near an altitude of 100 km and the other about 20–25 km higher.

551.510.535 2969
Geophysical Effects of High-Altitude Nuclear Explosions—T. Obayashi, S. C. Coroniti and E. T. Pierce. (*Nature, London*, vol. 183, pp. 1476–1478; May 23, 1959.) A report of observations made at Miraiso Observatory on August 1 and 12, 1958. Fade-outs on frequencies between 10 and 20 mc and an enhancement of atmospheric noise at 28 kc have been recorded. These effects are attributed to an increase in *D*-layer ionization extending over much greater distances than had previously been envisaged.

551.510.535 2970
Sporadic *E*-Region Ionization, "Spread *F*," and the Twinkling of Radio Stars—D. F. Martyn. (*Nature, London*, vol. 183, pp. 1382–1383; May 16, 1959.) Kinematic instability in the ionization gradient of a medium drifting across a magnetic field is considered to be responsible for the three phenomena.

551.510.535 2971
The Effect of Sudden Ionospheric Disturbances (S.I.D.'s) on 2.28-Mc/s Pulse Reflections from the Lower Ionosphere—F. F. Gardner. (*Aust. J. Phys.*, vol. 12, pp. 42–53; March, 1959.) During a typical large S.I.D., associated with a class 2 or class 3 flare, the increase in ionization might vary from 20/1 at 65 km through 3/1 at 90 km to unity at 110 km. The amplitude recovery of the *E*-layer echo lagged about 4 minutes behind the recovery of the lower echoes around 85 km. At all heights below 85 km, echo recovery occurred simultaneously.

551.510.535:621.396.11 2972
Rocket Measurements of Absorption in the Lower Ionosphere—H. Mende, K. Rawer and E. Vassy. (*Ann. Geophys.*, vol. 13, pp. 231–233; July–September, 1957.) Results are given of measurements of the field strength of two medium-wave and one long-wave transmitter. The *D*-layer minimum height is about 70 km and medium-wave observations indicate maximum absorption at 80 km, the attenuation being 1.2 db/km for normal incidence.

551.510.535:621.396.11:523.164 2973
Refraction of Extraterrestrial Radio Waves in the Ionosphere—M. M. Komesaroff and C. A. Shain. (*Nature, London*, vol. 183, pp. 1584–1585; June 6, 1959.) Expressions are derived for estimating ionospheric refraction at low frequencies. Horizontal gradients of electron density are considered. Positions of a discrete source obtained from observation at 19.7 mc after applying corrections for refraction are within a few minutes of arc of the observed position at 85.5 mc.

551.594 2974
Simultaneous Occurrence of Sub-visual Aurorae and Radio Noise Bursts on 4.6 kc/s—R. A. Duncan and G. R. Ellis. (*Nature, London*, vol. 183, pp. 1618–1619; June 6, 1959.) Records show that there is a correlation between aurorae and noise bursts but anomalies exist which cannot be explained satisfactorily.

551.594.5 2975
Auroral Isochasms—B. Hultqvist. (*Nature, London*, vol. 183, pp. 1478–1479; May 23, 1959.) Observed isochasms and projections of circles in the equational plane along the geomagnetic lines of force are compared.

551.594.6:621.372.57:621.3.087.4 2976
Investigation of an Apparatus for Recording Atmospherics—Benoit and Kernevez. (See 2870.)

551.594.6:621.396.11.029.45/.51:551.510.535 2977
An Experimental Proof of the Mode Theory of V.L.F. Ionospheric Propagation—Obayashi, Fujii and Kidokoro. (See 3094.)

LOCATION AND AIDS TO NAVIGATION

621.396.93 2978
Radio Aids to Navigation—(*Engineering, London*, vol. 186, pp. 313–323; September 5, 1958.) Three papers presented at the British Association meeting in Glasgow, September, 1958.

1) **Position Finding by Radio**—R. L. Smith-Rose (pp. 313–315).
2) **Marine Radio Navigational Aids**—B. G. Pressey (pp. 316–318).
3) **Radio Aids and Aeronautical Navigation**—C. Williams (pp. 318–323).

621.396.96 2979
Doppler Radar Navigation—F. B. Berger. (*Electronics*, vol. 32, pp. 62–63; May 8, 1959.) A table of characteristics of existing airborne systems.

621.396.96:621.314.63 2980
Using Silicon Diodes in Radar Modulators—Gray. (*Electronics*, vol. 32, pp. 70–72; June 12, 1959.) (See 3110.)

621.396.963:621.374.32 2981
Digital-Counter Techniques Increase Doppler Uses—B. E. Keiser. (*Electronics*, vol. 32, pp. 46–50; May 22, 1959.) The frequency of an oscillator is adjusted automatically to the Doppler frequency of the returned signal and is measured using a circuit which counts 100 pulses per 360° cycle.

621.396.969.3 2982
"Ring Angels" over South-East England—E. Eastwood, J. D. Bell and N. R. Phelp. (*Nature, London*, vol. 183, pp. 1759–1760; June 20, 1959.) The unexplained phenomena described have been observed on high-power *L*-band radar equipment during the sunrise period at heights up to 2000 feet. The rings expand as ripples at a velocity of 25–55 mph, the maximum diameter recorded being 30 miles.

621.396.969.33 2983
"Escort"—a Marine Radar with Unusual Features—(*Beama Jour.*, vol. 66, pp. 57–59; May, 1959.) Four types of PPI display can be selected and provision is made for automatic resetting of the ship's own position on the display and for automatic alignment correction.

621.396.969.34+621.396.934 2984
Anti-aircraft Radiolocation Techniques—K. Trofimov. (*Radio, Moscow*, pp. 27–31; February, 1958.) A description of radar techniques for the location of enemy aircraft and their destruction by guided missiles.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5:621.385.032.22 2985
Measurements of Gas Evolution or Sorption of Anode Materials under Simulated Life Conditions—C. H. Reiskopf. (*Sylvania Technologist*, vol. 11, pp. 114–116; October, 1958.) A brief description of techniques and results of measurements.

538.58 2986
Electrical Absorption of Gases in the High-Vacuum Pressure Range—G. Strotzer. (*Z. angew. Phys.*, vol. 10, pp. 207–216; May, 1958.) Various hypotheses for the "clean-up" effect in low-pressure gases are investigated.

535.215:538.6:546.682.86 2987
Indium Antimonide Photoelectromagnetic Infrared Detector—P. W. Kruse. (*J. Appl. Phys.*, vol. 30, pp. 770–778; May, 1959.) The theory of operation, construction, and performance data are presented.

535.215:539.2 2988
Photoconductor Performance, Space-Charge Currents, and the Steady-State Fermi Level—A. Rose and M. A. Lampert. (*Phys. Rev.*, vol. 113, pp. 1227–1235; March 1, 1959.) "The performance of a photoconductor is analyzed, via the concept of the steady-state Fermi level, and shown to be limited by the injection of space charge. Using the gain-bandwidth product G/τ_0 as a measure of performance, it is found that $G/\tau_0 = M/\tau_r$, where τ_r is the dielectric relaxation time under operating conditions, and $M = \mathfrak{N}_A/\mathfrak{N}_T$, with $e\mathfrak{N}_A$ the total charge on the anode and $e\mathfrak{N}_T$ the total volume charge, free plus trapped, effectively in thermal contact with the free charge."

535.215:546.472.21 2989
Anomalous Photovoltaic Effect in ZnS Single Crystals—A. Lempicki. (*Phys. Rev.*, vol. 113, pp. 1204–1209; March 1, 1959.) Photovoltages larger than the band gap have been observed in both cubic and hexagonal crystals free of such faults.

535.215:546.482.21 2990
Lattice Scattering Mobility of Electrons in Cadmium Sulphide—H. Miyazawa, H. Maeda and H. Tomishima. (*J. Phys. Soc. Japan*, vol. 14, pp. 41–47; January, 1959.) The temperature variation of the lattice scattering mobility is found to be given by the expression $\mu_L = A\{\exp(\Theta/T) - 1\}$ with $A = 92.5 \pm 15$ cm^2/sec and $\Theta = 370 \pm 30°$K. The Conwell-Weisskopf formula is used to correct for impurity scattering.

535.215:546.482.21 2991
Polarization of Photoconductivity Excitation Bands in CdS Single Crystals—R. L. Kelly and W. J. Fredericks. (*Phys. Rev. Lett.*, vol. 2, pp. 389–390; May 1, 1959.) The wavelength of incident light exciting maximum photoconductivity was measured as a function of its angle of polarization with respect to crystal orientation. Results are interpreted with an energy-level model.

535.215:546.482.21:538.63 2992
Relaxation-Time Anisotropy in Cadmium Sulphide Studied with Electrical Resistivity and Magneto-resistance Effect—T. Mazumi. (*J. Phys. Soc. Japan*, vol. 14, pp. 47–56; January, 1959.) Experimental results indicate unusual anisotropic temperature dependence of the galvanomagnetic effects in hexagonal CdS single crystal.

535.215:546.482.21:539.23 2993
Electric Breakdown of Vapour-Deposited CdS Films—C. W. Böer, U. Kümmel and W. Misselwitz. (*Naturwiss.*, vol. 45, pp. 331; July, 1958.) Breakdown field strength is plotted as a function of film thickness for both polarities of the applied voltage.

535.215:546.817.221:539.23 2994
Effect of Thickness of Thin Films of Lead Sulphide on the Spectral Response of Photoconductivity—H. E. Spencer. (*Phys. Rev.*, vol. 113, pp. 1417–1420; March 15, 1959.)

535.215:548.73 2995
Crystal Structure of Sodium-Potassium Antimonide (Na_2KSb)—J. J. Scheer and P. Zalm. (*Philips Res. Rep.*, vol. 14, pp. 143–150; April, 1959.) The structure of Na_2KSb, a photoemissive material, has been determined by X-ray analysis. It closely resembles that of Cs_3Sb.

535.37 2996
Two-Stage Optical Excitation in Sulphide Phosphors—R. E. Halsted, E. F. Apple and J. S. Prener. (*Phys. Rev. Lett.*, vol. 2, pp. 420–421; May 15, 1959.) Optical evidence shows that the same impurities give rise to electron transitions involving energy levels near or in the valence band as well as the conduction band.

535.37:061.3 2997
Transactions of the 5th Conference on Luminescence (Crystal Phosphors)—(*Izv. Ak. Nauk SSSR*, vol. 21, pp. 475–784; April and May, 1957.) The text is given of 98 papers presented at the conference held in Tartu, Estonia, June 25–30, 1956. For a list of titles in English, see *Translated Contents Lists of Russian Periodicals*, February and May, 1958, nos, 107 and 110, pp. 43–45 and 47–50.

535.37:539.2 2998
Energy-Level Positions of Silver Luminescent Centres in Sulphides—C. C. Klick. (*Phys. Rev. Lett.*, vol. 2, pp. 418–420; May 15, 1959.)

535.37:546.472.21 2999
Excitation Spectra and Temperature Dependence of the Luminescence of ZnS Single Crystals—A. Halperin and H. Arbell. (*Phys. Rev.*, vol. 113, pp. 1216–1221; March 1, 1959.) "The luminescence of ZnS:Cl and ZnS:Cu:Cl crystals was measured for the temperature region 80–500°K and for different wavelengths of exciting light. The behavior of the luminescence versus temperature curves differed from similar curves for powders reported in literature."

535.376 3000
A.C.-D.C. Electroluminescence—W. A. Thornton. (*Phys. Rev.*, vol. 113, pp.1187–1191; March 1, 1959.) The addition of a direct voltage to an alternating voltage exciting visible electroluminescence in certain ZnS powders increases the emission by as much as 250 times under conditions where the dc luminescence alone is about equal to the initial ac luminescence.

535.376 3001
Rise and Decay of Intensity of Luminescence of Short-Persistence Phosphors—R. Feinberg. (*Nature, London*, vol. 183, pp. 1546–1547; May 30, 1959.) Results of measurements made on three cathode-ray tube phosphors are discussed in relation to theory.

535.376:537.533.2 3002
Investigations of Exo-electron Emission and Luminescence of Inorganic Crystals—G. Gourgé. (*Z. Phys.*, vol. 153, pp. 186–206; November 14, 1958.) The investigations discussed were carried out to determine the relation between exo-electron emission and luminescence; measurements were made at temperatures down to $-165°C$.

535.376:546.281.26 3003
Electroluminescence of Silicon Carbide—D. Rücker. (*Z. angew. Phys.*, vol. 10, pp. 254–263; June, 1958.) The external and internal light emission observed on a dc-excited SiC junctions [see, *e.g.*, 3890 of 1957 (Patrick)] is investigated on blue and green single crystals, and an interpretation of the various effects is given.

535.376:546.482.21 3004
On the Mechanism for Carrier Excitation in CdS—D. D. Snyder, C. E. Bleil (*J. Appl. Phys.*, vol. 30, pp. 736–739; May, 1959.) The production and absorption of X-rays in the experimental crystals have been calculated and some confirmatory data presented.

535.376:546.561–31 3005
Electroluminescence in Cuprous Oxide—R. Frerichs and R. Handy. (*Phys. Rev.*, vol. 113, pp. 1191–1198; March 1, 1959.) The electroluminescent properties of Cu_2O are not directly analogous to those of a semiconductor such as Ge or an insulating phosphor such as ZnS. A detail study has been made of current creep effects occurring in Cu_2O plate rectifiers with dc excitation.

537.226/.228.1 3006
Studies on (Ba-Pb) (Ti-Zr)O_3 System—T. Ikeda. (*J. Phys. Soc. Japan*, vol. 14, pp. 168–174; February, 1959.)

537.226/.227:546.431.824–31 3007
Polarization Reversal in Barium Titanate—(*Bell Lab. Rec.*, vol. 37, p. 144; April, 1959.) A note on the polarization reversal in single crystals which occurs by extensive sideways motion of domain walls. See 155 of January (Miller).

537.227:547.476.3 3008
Ferroelectric Hysteresis and After-Effect Phenomena in Rochelle Salt—H. E. Müser. (*Z. angew. Phys.*, vol. 10, pp. 249–254; June, 1958.) Investigation of the constriction of ferroelectric hysteresis loops observed in Rochelle salt. For a similar anomaly in $BaTiO_3$ see, *e.g.*, 2757 of 1958 (Hegenbarth)

537.228.1:549.514.51 3009
β-Quartz as High-Temperature Piezoelectric Material—D. L. White. (*J. Acoust. Soc. Amer.*, vol. 31, pp. 311–341; March, 1959.) Lengthwise extensional, face shear and thickness shear modes can be excited piezoelectrically by suitable rotation of the crystal plate.

537.311.33 3010
On a Simple Model for Impurity-Band Conduction—K. Helmers. (*Philips Res. Rep.*, vol. 14, pp. 1–10; February, 1959.) A study of the influence of impurity-center distribution on the resistance of the sample using a stochastic resistance network.

537.311.33 3011
Some Optical Characteristics of Semi-Conductors—O. Simpson. (*Research, London*, vol. 12, pp. 127–132; April, 1959.) A number of optical phenomena are described and related to the electronic structure of semiconductors.

537.311.33 3012
Space Charge in Semiconductors resulting from Low-Level Injection—M. Green. (*J. Appl. Phys.*, vol. 30, pp. 744–747; May, 1959.) A solution of the continuity equations is obtained for the space-charge distribution by assuming that 1) deviations from neutrality are small, and 2) the space-charge fields give rise to pure diffusion and pure "drift-wave" terms with time-dependent coefficients.

537.311.33 3013
Role of Single Phonon Emission in Low-Field Breakdown of Semiconductors at Low Temperatures—M. A. Lampert, F. Herman and M. C. Steele. (*Phys. Rev. Lett.*, vol. 2, pp. 394–397; May 1, 1959.) Observations of low-field breakdown are correlated with the known energy-band structure and phonon spectra of Ge and Si. A simple, necessary condition for breakdown is suggested.

537.311.33:535.34–15 3014
Effect of Pressure on the Infrared Absorption of Semiconductors—L. J. Neuringer. (*Phys. Rev.*, vol. 113, pp. 1495–1503; March 15, 1959.) Measurements were made on Ge, Si, and Te in the pressure range 1–2000 atm. The pressure coefficients were used to calculate the thermal dilation term in the equation for the change of the energy gap with temperature and hence the magnitude of the electron-lattice interaction.

537.311.33:537.32 3015
On the Theory of the Thermoelectricity in Two-Band Semiconductors—E. Haga. (*J. Phys. Soc. Japan*, vol. 14, pp. 35–38; January, 1959.) A theory is developed taking account of the temperature dependence of the energy gap. The Thomson relations are shown to be satisfied.

537.311.33:537.533 3016
Field Emission from Semiconductors—G. Busch and T. Fischer. (*Brown Boveri Rev.*, vol. 45, pp. 532–539; November/December, 1958.) Theoretical and experimental work on field emission is reviewed. Results are discussed of an investigation carried out on SiC point electrodes, which confirm the exponential relation between current and field which is characteristic of field emission.

537.311.33:538.214 3017
The Effect of Concentration on the Magnetic Susceptibility of Trapped Electrons and Holes in Semiconductors—F. T. Hedgcock. (*Can. J. Phys.*, vol. 37, pp. 381–383; March, 1959.) A model proposed to explain the anomalous magnetic susceptibility of certain impurity semiconductors at low temperatures [see 2800 of 1957 and 3513 of 1958 (Sonder and Stevens)] is found to be attractive qualitatively but quite inadequate quantitatively.

537.311.33:538.614 3018
The Faraday Effect in Anisotropic Semiconductors—I. G. Austin. (*J. Electronics Control*, vol. 6, pp. 271–274; March, 1959.) "The theory of the Faraday effect in semiconductors is extended to uniaxial crystals with spheriodal energy surfaces, using the classical Drude-Zener theory. Expressions applicable at infrared frequencies are given and used to discuss preliminary measurements on Bi_2Te_3."

537.311.33:[546.28+546.289 3019
Semiconductor Surface Phenomena—A. Many. (*Sylvania Technologist*, vol. 11, pp. 117–124; October, 1958.) "Slow" and "fast" surface states have been established for Ge and Si; their characteristics are summarized and discussed.

537.311.33:[546.23+546.289 3020
Metallurgy of Semiconductors, in Particular Germanium and Silicon—A. J. Goss. (*Marconi Rev.*, vol. 22, pp. 3–17; 1st Quarter, 1959.) 54 references.

537.311.33:546.28 3021
The Effects of Seed Rotation on Silicon Crystals—A. J. Goss and R. E. Adlington. (*Marconi Rev.*, vol. 22, pp. 18–36; 1st Quarter 1959.) Single crystals pulled in an argon atmosphere at rotation rates up to 200 rpm have been examined. The effect of rotation on crystal pulling, the growth interface, dislocations, etching, resistivity, 9-μ absorption data and heat treatment of the crystal are given. Results are discussed in relation to a mechanical model of stirring in the melt.

537.311.33:546.281.26 3022
Some Surface Properties of Silicon-Carbide Crystals—J. A. Dillon, Jr., R. E. Schlier and H. E. Farnsworth. (*J. Appl. Phys.*, vol. 30, pp. 675–679; May, 1959.) Both work-function and

electron-diffraction studies indicated that SiC surfaces obtained by ion bombardment and annealing were nonstoichiometric.

537.311.33:546.289 **3023**
High-Electric-Field Effects in Germanium *p-n* Junction—J. Yamaguchi and Y. Hamakawa. (*J. Phys. Soc. Japan*, vol. 14, pp. 15–21; January, 1959.) Increase of ambient temperature caused the critical voltage for avalanche breakdown to increase and the voltage for the onset of negative resistance to decrease. The barrier temperature was independent of the ambient temperature.

537.311.33:546.289 **3024**
Barrier Temperature at Turnover in Germanium *p-n* Junction—J. Yamaguchi and Y. Hamakawa. (*J. Phys. Soc. Japan*, vol. 14, pp. 232–233; February, 1959.)

537.311.33:546.289 **3025**
Injection and Extraction of Minority Carriers at the Surface of a Germanium Electrode as a Result of Electrochemical Processes—Yu. V. Pleskov. (*Dokl. Ak. Nauk SSSR*, vol. 126, pp. 111–1114; May 1, 1959.)

537.311.33:546.289 **3026**
Sb Distribution in Quenched Ge-Sb Alloys—G. Pröpstl and G. Zielasek. (*Z. angew. Phys.*, vol. 10, pp. 201–204; May, 1958.) The distribution of Sb in alloys prepared for doping Ge single crystals is investigated using a radioactive isotope. A considerable degree of inhomogeneity is observed in spite of rapid quenching. This difficulty can be overcome by zone melting.

537.311.33:546.289:535.215 **3027**
The Photoconduction of Germanium after Bombardment with Fast Electrons—F. Stöckmann, E. E. Klontz, J. McKay, H. Y. Fan and K. Lark-Horovitz. (*Z. Phys.*, vol. 153, pp. 331–337; December 5, 1958.) The spectral distribution of photoconduction was measured on differently doped specimens of single-crystal Ge after bombardment with 4.5-mev electrons.

537.311.33:546.289:584.4 **3028**
The Generation of Dislocations by Thermal Stresses—P. Penning. (*Philips Tech. Rev.*, vol. 19, pp. 357–364; August 22, 1958.) A study is made of etch-pit distribution over the cross section of a Ge rod to assess the influence of the cooling rate on its internal perfection. The theoretical dislocation distribution is calculated assuming that stresses are only partially relieved by plastic flow. Results are in good agreement with observations. See also 2459 of 1958.

537.311.33:546.289:548.5 **3029**
The Pulling of Germanium Single Crystals from "Floating Crucibles"—J. Goorissen and F. Karstensen. (*Z. Metallkde*, vol. 50, pp. 46–50; January, 1959.) The floating-crucible technique is described and its theoretical yield is compared with that of the Czochralski and zone-refining methods.

537.311.33:546.623.86 **3030**
The Formation of Barrier Layers in Aluminium Antimonide by the Alloying Method—H. J. Henkel. (*Z. Metallkde.* vol. 50, pp. 51–53; January, 1959.) A *p-n* function is produced by alloying *n*-type AlSb with Zn-doped aluminum foil.

537.311.33:546.681.241 **3031**
The Change in the Crystal Structure of Gallium Telluride (Ga_2Te_2) Doped with Copper—G. Harbeke and G. Lautz. (*Naturwiss.*, vol. 45, pp. 283–284; June, 1958.)

537.311.33:546.682.19 **3032**
Effect of Heat Treatment upon the Electrical Properties of Indium Arsenide—J. R. Dixon and D. P. Enright. (*J. Appl. Phys.*, vol. 30, pp. 753–759; May, 1959.) Large reversible variations in carrier concentration, Hall mobility, and carrier lifetime have been produced in InAs by heat treatment. The observed phenomena are consistent with a model involving the segregation and dispersion of donor impurities to and from dislocations.

537.311.33:546.682.86 **3033**
Properties of the Semiconductor InSb—M. Rodot. (*J. Phys. Radium*, vol. 19, pp. 140–150; February, 1958.) Properties are reviewed with special reference to the value of the effective mass of the electrons and the scattering mechanism. The theory of thermoelectric and thermomagnetic effects is given and experimental results are presented. See 2469 of 1958.

537.311.33:546.824–31 **3034**
Infrared Absorption of Reduced Rutile TiO_2 Single Crystals—D. C. Cronemeyer. (*Phys. Rev.*, vol. 113, pp. 1222–1226; March 1, 1959.)

538:061.3 **3035**
Transactions of the 3rd Conference on the Physics of Magnetic Phenomena—(*Izv. Ak. Nauk SSSR*, vol. 61, pp. 787–904, 1038–1212 and 1215–1336; June, August, and September, 1957.) The text is given of 74 papers presented at the conference held in Moscow, May 23–31, 1956. For a list of titles in English, see *Translated Contents Lists of Russian Periodicals*, nos. 110 and 111, pp. 50–51 and 32–34; May and June, 1958.

538.22:538.569.4 **3036**
Indirect Coupling of Nuclear Spins in Antiferromagnet with Particular Reference to MnF_2 at Very Low Temperatures—T. Nakamura. (*Prog. theoret. Phys., Japan*, vol. 20, pp. 542–552; October, 1958.) The line width ($\sim$14 oersteds) of the F^{19} nuclear magnetic resonance in MnF_2 at 1.4°K observed by Jaccarino and Shulman (527 of 1958) is shown to come mainly from indirect coupling of nuclear spins through hyperfine interaction with spin waves. The line width of the MnS resonance is about 600 oersteds.

538.22:538.569.4:621.375.9 **3037**
Two-Level Maser Materials—R. H. Hoskins. (*J. Appl. Phys.*, vol. 30, p. 797; May, 1959.) Comment on some advantages of paramagnetic ions in ionic crystals as materials for two-level solid-state masers.

538.221 **3038**
Distribution of Magnetic Domains between the Two Phases in a Single-Crystal Flat Disk of Iron—K. F. Niessen. (*Philips Res. Rep.*, vol. 14, pp. 101–110; April, 1959.)

538.221:539.23 **3039**
Magnetic Properties of Very Thin Films of Nickel—G. Goureaux and A. Colombani. (*Compt. Rend. Acad. Sci., Paris*, vol. 248, pp. 543–546; January 26, 1959.)

538.221:539.234:538.63 **3040**
Determination of the Distribution of Orientation of the Magnetization Vectors in Nickel and Iron Vapour-Deposited Films using the Magnetoresistance Effect—W. Hellenthal. (*Z. Phys.*, vol. 153, pp. 359–371; December 5, 1958.)

538.221:621.134 **3041**
Temperature Dependence of the Paramagnetic Susceptibility of Nickel-Zinc Ferrites—V. I. Chechernikov and Yu. D. Volkov. (*Zh. eksp. teor. Fiz.*, vol. 35, pp. 875–879; October, 1958.) The reciprocal of molar susceptibility for a range of Ni-Zn ferrites is plotted as a function of temperature in the range 300°–1500°K. Near the ferromagnetic Curie point the dependence of specific magnetization σ on magnetic field strength H is expressed in the form $H = a\sigma + b\sigma^3$, where the coefficients a and b depend on temperature and pressure.

538.221:621.318.134:538.569.4 **3042**
Magnetic Resonance Studies in the Reaction of Nickel Cobalt Ferrite—S. L. Blum and M. H. Sirvetz. (*J. Appl. Phys.*, vol. 30, p. 795; May, 1959.) Use is made of the analysis of ferromagnetic-resonance line shapes to obtain indications of the course of the reaction as a function of the reaction conditions.

538.221:621.318.134:538.569.4.029.64 **3043**
Microwave Resonance in Gadolinium-Iron Garnet Crystals—W. V. Smith, J. Overmeyer and B. A. Calhoun. (*IBM J. Res. & Dev.*, vol. 3, pp. 153–162; April, 1959.) Ferrimagnetic resonance at 9497 and 23725 mc is described in terms of a two-sublattice model.

538.221:621.318.134:621.318.57 **3044**
Reciprocity Relationships for Gyrotropic Media—R. F. Harrington and A. T. Villeneuve. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 308–310; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

538.221:621.318.134:621.375.9 **3045**
Power-Flow Relations in Lossless Nonlinear Media—H. A. Haus. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 317–324; July, 1958. Abstract, PROC. IRE, vol. 46, p. 1777; October, 1958.)

621.315.3(083.7) **3046**
Wire in the Electronic Industry—(*Electronic Ind.*, vol. 17, pp. 89, 97; December, 1958.) U. S. specifications, wire codes and general information are tabulated.

621.793:621.3.049.75 **3047**
Electroless Copper Plating in Printed Circuitry—E. B. Saubestre. (*Sylvania Technologist*, vol. 12, pp. 6–11; January, 1959.) The deposition of copper films on plastic printed-circuit boards by chemical reduction is discussed, and a procedure for producing "plated-through" holes is described. An extension of the plating process for unclad laminates is noted.

MATHEMATICS

512:621.318.57:681.142 **3048**
Classification and Minimization of Switching Functions: Part 1—N. C. de Troye. (*Philips Res. Rep.*, vol. 14, pp. 151–193; April, 1959.) An attempt to find either the minimal sum of products or the minimal product of sums from a given Boolean function.

516.7:621.3 **3049**
Geometric-Analytic Theory of Transition in Electrical Engineeriug—E. F. Bolinder. (PROC. IRE, vol. 47, pp. 1124–1129; June, 1959.)

517.942.9:517.949.8 **3050**
Numerical Solution of Laplace's Equation, given Cauchy Conditions—I. Sugai. (*IBM J. Res. & Dev.*, vol. 3, pp. 187–188; April, 1959.) An expression giving the order of magnitude of the propagated errors is obtained for numerical analysis by methods of finite differences. For the practical aspect in the design of electron guns with curved electron trajectories see PROC. IRE, vol. 47, pp. 87–88; January, 1959.

MEASUREMENTS AND TEST GEAR

621.3.011.4(083.74) **3051**
The Cylindrical Cross-Capacitor as a Calculable Standard—A. M. Thompson. (*Proc. IEE*, Part B, vol. 106, pp. 307–310; May, 1959.) The capacitor consists of a hollow conducting cylin-

der divided into four insulated sections by gaps parallel to the axis. A practical form described consists of four parallel bars of circular cross section. The capacitance can be computed with precision.

621.3.018.41(083.74) 3052
A Portable Frequency Standard—L. F. Koerner. (*Bell Lab. Rec.*, vol. 37, pp. 173–176; May, 1959.) Description of a unit, the size of a miniature camera, which operates at about 15 mc with an accuracy within 1 part in 10^6.

621.3.018.41(083.74) 3053
Construction of a Mobile Caesium Frequency Standard—A. H. W. Beck and J. Lytollis. (*Proc. IEE*, Part B, vol. 105, supplement no. 11, pp. 712–715; 1958. Discussion.) Practical details of the construction of a sealed-off version are given.

621.3.018.41(083.74):538.569.4 3054
Construction and Application of a Frequency Standard for Microwave Spectrometers—H. G. Fitzky. (*Z. angew. Phys.*, vol. 10, pp. 297–303; July, 1958.) A 10-mc crystal oscillator and frequency multiplication to 1080 mc are used in the equipment described for measurements of frequency up to 25 kmc with an accuracy of better than 1 in 10^7.

621.317.3:621.396.822 3055
Measurement of Equivalent Noise Resistance of a Noise-Thermometer Amplifier—H. Pursey and E. C. Pyatt. (*J. Sci. Instr.*, vol. 36, pp. 260–264; June, 1959.) Amplifier noise is compared with that of a wire-wound resistance at a standard temperature, using a vibrating switch to connect the sources alternately to a single channel. An accuracy within 1 per cent is obtained.

621.317.4:538.569.4 3056
Measurement of Magnetic Flux Density by Paramagnetic Resonance—C. P. Allen and M. Sherry. (*J. Electronics Control*, vol. 6, pp. 264–270; March, 1959.) The method is based on measurement of the frequency of paramagnetic resonance in an organic compound. It uses a simple coaxial-line probe unit and enables flux densities in the range of a few hundreds up to some thousands of gauss to be measured to an absolute accuracy of ± 0.06 per cent.

621.317.4:621.3.042.1:621.397.62 3057
Magnetic Measurements on Ferrite U-Cores for Horizontal-Deflection Output Transformers—R. Fälker and E. E. Hücking. (*Elektron. Rundschau*, vol. 12, pp. 270–274; August, 1958.) Methods of measurement are reviewed and a specially designed core tester is described.

621.317.42:550.385 3058
The Influence of the Self-Inductance of Magnetic-Core Windings used for the Recording of Rapid Variations of the Earth's Magnetic Field—G. Grenet. (*Ann. Géophys.*, vol. 13, pp. 249–251; July/September, 1957.)

621.317.61:621.385.1 3059
A Method for the Accurate Measurement of Mutual Conductance of Thermionic Valves—M. R. Child and D. J. Sargent. (*Proc. IEE*, Part B, vol. 106, pp. 311–314; May, 1959.) Absolute errors are estimated to be less than 0.25 per cent, and comparative error less than 0.1 per cent. Adaptations for measurement of anode conductance and screen-grid amplification factor are described.

621.317.7:621.314.7 3060
A Transistor Characteristic Curve Tracer—J. F. Young. (*Electronic Engrg.*, vol. 31, pp. 330–336; June, 1959.) "A Dekatron is used to develop a stepped voltage controlling the base current of the transistor under test. At each step a half sinusoidal voltage is applied to the transistor and the resulting collector current is plotted against voltage on an external oscilloscope. A series resistor provides the current signal and limits the transistor dissipation. The unit can also be used to plot the characteristics of normal or of Zener diodes."

621.317.733:621.375.2.024 3061
Use of a Direct-Current Amplifier and Recorder to Balance a Mueller Resistance Bridge—G. T. Armstrong, P. K. Wong and L. A. Krieger. (*Rev. Sci. Instr.*, vol. 30, pp. 339–343; May, 1959.) Methods of reducing system noise to give improved sensitivity.

621.317.733.011.4:621.372.54 3062
The Balanced Unsymmetrical Parallel-T Network as a Three-Terminal Frequency-Dependent Bridge for the Measurement of Capacitance and Dissipation Factor—K. Posel. (*Trans. S. Afr. Inst. Elec. Eng.*, vol. 49, Part 8, pp. 287–298; August, 1958.) The theory of operation of the bridge and its design are detailed. See also 2656 of 1958.

621.317.733.029.62 3063
Coaxial Displacement Dielectric Cell for Liquids Usable to 350 Mc/s—S. E. Lovell and R. H. Cole. (*Rev. Sci. Instr.*, vol. 30, pp. 361–362; May, 1959.) Construction details of a bridge element useful in the determination of capacitance, dielectric loss, or conductivity.

621.317.74:534.2-8:621.373.52 3064
Zero-Crossing Technique syncs Wave-Train Outputs—J. A. Wereb, Jr. (*Electronics*, vol. 32, pp. 64–65; May 8, 1959.) A technique for producing a sinusoidal wave-train starting from the zero-crossing point of another sine wave. The generator is used in testing ultrasonic equipment.

621.317.75.087.6 3065
Homodyne Detector for Reproduction of Periodic Waveforms—C. Lagercrantz. (*J. Sci. Instr.*, vol. 36, pp. 257–259; June, 1959.) An AF signal is scanned using 20-μ gating impulses whose phase is shifted slowly and linearly. The gated output is recorded on a pen recorder. The circuit and performance tests are described.

621.317.763.029.64:621.372.413 3066
The Design of Broad-Band Circular Wavemeters—P. Andrews. (*Brit. Commun. Electronics*, vol. 6, pp. 354–357; May, 1959.) The design is considered mainly with cylindrical cavities in the TE_{11} mode. Mode suppression and the temperature coefficient of wavemeters are treated.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.721:621.397.9 3067
The Video Differential Planimeter—M. Tobin. (*Rev. Sci. Instr.*, vol. 30, pp. 323–327; May, 1959.) Description of an instrument for measuring variations in the projected area of a remote object by means of a television camera system or flying-spot scanner.

538.566.029.6:541.126 3068
Observations of Detonation in Solid Explosives by Microwave Interferometry—G. F. Cawsey, J. L. Farrands and S. Thomas (*Proc. Roy. Soc. A.*, vol. 248, pp. 499–521; December 9, 1958.) Confined detonation processes have been studied by a method noted earlier [1833 of 1956 (Farrands & Cawsey)], using apparatus developed from that described by Froome (3532 of 1952).

550.340:621.3.087.6 3069
An Electronic Seismic Transducer for Visual Recording—P. Gouin. (*Ann. Geophys.*, vol. 13, pp. 234–241; July/September, 1957. In English.) A detailed description of the capacitance-type transducer, amplifier and recorder.

551.508.71:621.372.413 3070
Recording Microwave Hygrometer—J. Sargent. (*Rev. Sci. Instr.*, vol. 30, pp. 348–355; May, 1959.) A description is given of a microwave refractometer designed at the National Bureau of Standards for measurement of low water-vapor pressures in a moving air stream.

621.384.6:621.319.3 3071
Electrostatic - Transformer - Type Particle Accelerator using Ceramic $BaTiO_3$-Ferrostac—T. Shibata, A. Toi and T. Suita. (*J. Phys. Soc. Japan*, vol. 14, p. 227; February, 1959.) A note on the construction of a 150-kv accelerator in which the hv generator has rotating ferroelectric disks which carry electric charges.

621.384.8:621.318.381:621.316.7.078.3 3072
Current and Field Stabilization of the 9-kW Electromagnet of the A.E.I. Magnetic Spectrograph—R. Bailey and E. C. Fellows. (*J. Brit. IRE*, vol. 19, pp. 309–321; May, 1959.) Signals obtained from nuclear resonance are used to control the strength of a magnetic field ± 0.01 per cent.

621.385.833 3073
Numerical Computation of Electrostatic Immersion Objectives—E. Hahn. (*Optik*, vol. 15, pp. 500–515; August, 1958.)

621.385.833 3074
Space-Charge Aberration and Resolving Power in Electron Microscopes—W. E. Meyer. (*Optik*, vol. 15, pp. 398–406; July, 1958.) Space-charge effects may limit the resolving power more than spherical aberration. Methods of reducing the influence of space charge are indicated.

621.385.833 3075
Stigmatic Image in Rotationally Asymmetric Electron Lenses—F. Lenz. (*Optik*, vol. 15, pp. 393–397; July, 1958.)

621.385.833:535.317.3 3076
Compensation of the Chromatic Dependence of Magnification in the Electrostatic Electron Microscope—W. Weitsch. (*Optik*, vol. 15, pp. 492–499; August, 1958.)

621.385.833:621.3.032.21 3077
Some Electron-Optical Properties of Point Cathodes—S. Maruse and Y. Sakaki. (*Optik*, vol. 15, pp. 485–491; August, 1958.) Experimental results show that electron emission of the point cathode is mainly determined by the Schottky effect. The use of the point cathode as a cold cathode in electron microscopes is discussed. See also 245 of 1957 (Sakaki and Möllenstedt).

621.385.833:621.3.032.213.6 3078
Oxide-Cored Cathode—K. Ando, O. Kamigaito, Y. Kamiya, S. Takahashi and R. Uyeda (*J. Phys. Soc. Japan*, vol. 14, pp. 180–185; February, 1959.) Description of a cathode for electron microscopy consisting of a drawn platinum wire filled with oxide powder. The method of preparation and performance tests are described.

621.387.424 3079
Improved Design for Halogen-Quenched End-Window Geiger Counters—K. van Duren and J. Hermsen. (*Rev. Sci. Instr.*, vol. 30, pp. 367–368; May, 1959.)

621.387.464 3080
Modern Development of Scintillation Counters—W. Hanle and H. Schneider. (*Z.

angew. Phys., vol. 10, pp. 228–248; May, 1958.) Detailed review of design, construction and applications. 242 references.

621.387.464:621.383.27 3081

The Resolving Power of Scintillation Multipliers and the Influence on it of Various Parameters—P. Görlich, A. Krohs, H. J. Pohl, R. Reichel and L. Schmidt. (*Z. angew. Phys.*, vol. 10, pp. 303–309; July, 1958.) Results of measurements on a photomultiplier for scintillation counting are discussed.

621.397.9:522.2 3082

Using TV Techniques in Astronomy—J. Borgman. (*Electronics*, vol. 32, pp. 66–68; May 8, 1959.) A variable star is detected by a differential photographic method which eliminates constant features. Television techniques are used to display the difference signals.

621.397.9:522.2 3083

Television Techniques in Astronomy—N. F. Kuprevich. (*Priroda*, pp. 50–54; March, 1958.) Two systems are described based on: 1) a two-stage electron-optical converter consisting of a photocathode emitting electrons which form an image on a 35-mm luminous screen with a possible increase of brightness up to 100–130 times; 2) the use of an orthicon-type 625-line television screen on which an image is obtained with magnification up to 6.5 times.

621.398 3084

Radio Telemetry: Part 1—Systems—A. J. Shimmins. (*Proc. IRE, Aust.*, vol. 19, pp. 775–787; December, 1958.) Factors which determine system performance are analyzed, taking as an example the R.A.E. subminiature FM/AM system.

621.398:616.831–073.97 3085

A Miniature Electroencephalograph Telemeter System—D. C. Gold and W. J. Perkins. (*Electronic Engrg.*, vol. 31, pp. 337–339; June, 1959.) Transmits the electrical activity of the brain of an unrestrained cat on a 6.8-mc AM carrier.

681.61:621.319 3086

High-Speed Read-Out for Data Processing—R. E. West. (*Electronics*, vol. 32, pp. 83–85; May 29, 1959.) Description of an electrostatic teletypewriter which can print more than 3000 words/min. Input pulses to the print heads charge the surface of paper to which powdered ink adheres.

PROPAGATION OF WAVES

621.396.11:550.389.2:629.19 3087

Radio Reflections from Satellite-Produced Ionization—Roberts, Kirchner and Bray. (See 2963.)

621.396.11:551.510.52 3088

The Role of Turbulent Mixing in Scatter Propagation—R. Bolgiano, Jr. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 161–168; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1438; July, 1958.)

621.396.11:551.510.52 3089

The Influence of Moisture in the Ground, Temperature and Terrain on Ground Wave Propagation in the V.H.F. Band—B. Josephson and Å. Blomquist. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 169–172; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.11:551.510.52 3090

Distance Dependence, Fading Characteristics and Pulse Distortion of 3000-Mc/s Transhorizon Signals—B. Josephson and G. Carlson. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 173–175; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.11:551.510.52 3091

Some Microwave Propagation Experiences from a "Just-Below-Horizon" Path—B. Josephson and F. Eklund. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 176–178; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1439; July, 1958.)

621.396.11:551.510.52 3092

The Diffraction of Electromagnetic Waves by the Earth's Curvature—a Theory of Tropospheric Propagation Near and Beyond the Radio Horizon—O. Tukizi. (*Rep. elect.Commun. Lab., Japan*, vol. 11, pp. 421–425; November, 1958.) Classical diffraction theory is modified to account for the slow rate of decrease of field-strength well beyond the horizon. A saddle-point method is used to take into account the contribution of all the terms of the residue series.

621.396.11:551.510.535:523.164 3093

Refraction of Extraterrestrial Radio Waves in the Ionosphere—Komesaroff and Shain. (See 2973.)

621.396.11.029.45/.51:551.510.535:551.594.6 3094

An Experimental Proof of the Mode Theory of V.L.F. Ionospheric Propagation—T. Obayashi, S. Fujii and T. Kidokoro. (*J. Geomag. Geoelect.*, vol. 10, no. 2, pp. 47–55; 1959.) VLF atmospherics are received on a receiver which continuously sweeps over the frequency band 5–70 kc. The output is displayed on an intensity-modulated cathode-ray tube which is photographed on continuously moving film. There is an intensity maximum near 10 kc and selective absorption bands which vary with time of day and may be associated with the cutoff frequencies of the earth-ionosphere waveguide. The effects of solar flares are also discussed.

621.396.11.029.63 3095

A Contribution to the Knowledge of Propagation Conditions at 1.3 Gc/s based on Measurements over a Transmission Path within Optical Range—U. Kühn. (*Tech. Mitt. BRF, Berlin*, vol. 1, pp. 4–10; October, 1957.) Statistical analysis of field-strength recordings taken in one year over an 82-km path, and comparison with meteorological data for the same period.

621.396.11.029.63 3096

Measurements of 1250-Mc/s Scatter Propagation as Function of Meteorology—D. L. Ringwalt, W. S. Ament and F. C. MacDonald. (IRE TRANS. ON ANTENNAS AND PROPAGATION, vol. AP-6, pp. 208–209; April, 1958.) Short detailed report and discussion of the results of measurements made over a 262-mile over-water path between Florida and the Bahamas in December 1956. Ground and airborne field-strength measurements, refractometer soundings, radiosonde data and visual observations were recorded.

621.396.11.029.63 3097

Apparent Correlation between Tropopause Height and Long-Distance Transmission Loss at 490 Mc/s—D. R. Hay. (PROC. IRE, vol. 47, pp. 1144–1145; June, 1959.) For a 640-mile path in June–July, 1957, signals were low and steady when the tropopause was low, but were higher and fluctuated more when it was high.

621.396.812 3098

Prolonged Signal Fade-Out on a Short Microwave Path—D. R. Hay and G. E. Poaps. (*Can. J. Phys.*, vol. 37, pp. 313–321; March, 1959.) During a period of one year, the incidence of signal fade-out has been observed in 2-kmc transmissions over a 21-mile path near Ottawa. Fade-out durations varied from a few minutes to several hours, with the most frequent occurrence in the summer and during the night. An analysis of the refractivity of the air at the middle of the radio path indicates that fade-out is associated with a shallow horizontal transition zone in vapor pressure at a level near the antenna heights.

RECEPTION

621.376 3099

Correlation Devices Detect Weak Signals—H. R. Raemer and A. B. Reich. (*Electronics*, vol. 32, pp. 58–60; May 22, 1959.) Operating principles of autocorrelators, cross-correlators, and radiometers are described.

621.396.621:621.314.7 3100

How to Design Reflexed Transistor Receivers—J. Waring. (*Electronics*, vol. 32, pp. 70–72; May 8, 1959.) Methods for obtaining IF and AF gain in the same stage without motorboating.

621.396.66:621.396.828 3101

Negative-Supply Outboard Codan—R. L. Ives. (*Audio*, vol. 43, pp. 22–23, 73; May, 1959.) Details are given of a circuit which silences the AF stages of a receiver when the carrier amplitude falls below a predetermined level. The circuit does not alter the characteristics of the receiver to which it is connected.

621.396.812.3:621.396.666 3102

Linear Diversity Combining Techniques—D. G. Brennan. (PROC. IRE, vol. 47, pp. 1075–1102; June, 1959.) An analysis and results of measurements of the relative performance are given for three types of diversity combining techniques: 1) selection diversity, 2) maximal-ratio diversity, and 3) equal-gain diversity systems. The effects of various departures from the ideal conditions are considered and the relative merits of predetection and postdetection combining and of long-term distributions are discussed.

STATIONS AND COMMUNICATION SYSTEMS

621.391 3103

On Asymmetric Information Channels—R. B. Banerji. (*J. Brit. IRE*, vol. 19, pp. 305–308; May, 1959.) A study of channel capacity in terms of the probability of possible errors, and application to PCM with amplitude keying.

621.396.3:621.391 3104

Some Operational Considerations Affecting the Use of Automatic Error Correcting Equipment on H. F. Telegraph Networks—E. G. Copper. (*Point to Point Telecommun.*, vol. 3, pp. 21–34; February, 1959.) A discussion of some of the problems associated with the radio error-correcting multiplex (REM) system.

621.396.5:534.76 3105

Compatible Stereo Radio using A.M./F.M. Multiplex—H. E. Sweeney. (*Electronics*, vol. 32, pp. 56–58; May 8, 1959.) Transmission of two channels by amplitude and frequency modulation of the same carrier. A circuit is given for the addition of a FM channel to an AM receiver.

621.396.65 3106

The TJ Radio System—S. D. Hathaway and H. H. Haas. (*Bell Lab. Rec.*, vol. 37, pp. 129–133; April, 1959.) Description of a 6-channel 11-kmc relay system using dual frequency-diversity transmission, giving details of arrangement of subcarriers in the spectrum and examples of use for telephony, television and data transmission.

621.396.65:621.396.41 3107
F.M. Multiplexing for Studio-Transmitter Links—D. Harkins. (*Electronics*, vol. 32, pp. 44–45; May 22, 1959.) Three program signals modulate subcarriers at 26, 65 and 175 kc, which are combined to modulate a 946-mc carrier for transmission to the transmitter site 16 miles away.

SUBSIDIARY APPARATUS

621.3.087.45:621.395.625.3 3108
A Multiple-Channel D.C. Recording System—H. D. Scott. (*Electronic Engrg.*, vol. 31, pp. 340–344; June, 1959.) Describes an AM system with tape-noise cancellation enabling up to twelve 0–10-cps channels to be recorded on a conventional single-track recorder together with speech and timing signals.

621.314.63:546.289 3109
The Thermal Behaviour of Semiconductor Rectifiers—O. Jakits. (*Brown Boveri Rev.*, vol. 45, pp. 540–644; November/December, 1958.) Measurements are described which were made on heavy-current Ge diodes to determine the thermal inertia. The effect of cooling on the overload characteristic is discussed.

621.314.63:621.396.96 3110
Using Silicon Diodes in Radar Modulators—M. G. Gray. (*Electronics*, vol. 32, pp. 70–72; June 12, 1959.) A peak power of 250 kw is developed using Si diodes for charging the artificial line and for clipping reverse voltage swings. The diodes dissipate instantaneous powers up to 300 kw.

621.314.634 3111
Selenium Rectifiers with Artificial Layers of Selenides of Cadmium, Tin, Bismuth and Lead—Y. Moriguchi. (*J. Phys. Soc. Japan*, vol. 14, pp. 152–167; February, 1959.) The action of various selenides as barrier layers has been investigated by measurement of the rectifier dc and ac characteristics. CdSe and SnSe layers play an important role in rectification but the selenides of Bi and Pb seem to be unsuitable. In general, the layer material should have a resistivity $<10^4\ \Omega$ cm.

621.314.64 3112
Current/Time Relationship in the Forward Direction of Electrolytic Rectifiers—W. C. van Geel and C. A. Pistorius. (*Phillips Res. Rep.*, vol. 14, pp. 123–131; April, 1959.) Qualitative explanation of the effects observed on applying alternating rectangular and sinusoidal voltages.

621.316.721.078:621.375.2.024 3113
Use of Operational Amplifiers in Precision Current Regulators—K. Eklynd. (*Rev. Sci. Instr.*, vol. 30, pp. 328–331; May, 1959.) Low-drift high-gain dc amplifiers in a control loop can reduce steady-state error.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24 3114
Carrier Transmission for Closed-Circuit Television—L. G. Schimpf. (*Electronics*, vol. 32, pp. 66–68; June 12, 1959.) A simple and inexpensive coaxial-cable transmission system, using transistors in the terminal and repeater circuits, is described. Dc supplies to the repeaters are applied via the signal cable.

621.397.611.2 3115
Measurement of the Transmission Characteristics of Television-Camera Preamplifiers—W. Eckardt. (*Tech. Mitt. BRF, Berlin*, vol. 1, pp. 27–32; December, 1957.)

621.397.62 3116
Two Realizations of the New Synchrophase—L. Chrétien and R. Aschen. (*TSF et TV*, vol. 33, pp. 71–76, 152–157, 167–168; March/May, 1957.) A rejector circuit and a variable video-frequency gain control compensate for phase distortion by altering the shape of the video-frequency response curve. Detailed descriptions are given of a medium-range and a long-range television receiver, with a note on the adjustment of the phase-correction circuit.

621.397.62 3117
Television I.F. Amplifiers with Linear Phase Response—A. N. Thiele. (*Proc. IRE Aust.*, vol. 19, pp. 652–668; November, 1958.) This type of response is discussed in relation to ease of tuning and alignment and to phase equalization at the transmitter.

621.397.62:535.623 3118
Automatic Controls for Colour Television—Z. Wiencek. (*Electronics*, vol. 32, pp. 58–59; May 15, 1959.) A method of control of the phase (hue) and amplitude (chroma) of the color signal using a low-frequency diode gate.

621.397.62:535.623:535.88 3119
The Projection of Colour-Television Pictures—T. Poorter and F. W. de Vrijer. (*Philips Tech. Rev.*, vol. 19, pp. 338–355; August 22, 1958.) Three projection-type cathode-ray tubes are used respectively with red, green and blue fluorescing phosphors. Each is mounted in a Schmidt optical system; the superposition of the three images is effected either by dichroic mirrors [1701 of May (van Alphen)] or by mounting the three tubes side by side. Projectors using these systems are described.

621.397.621.2 3120
Noise-Immune Synchronizing Circuits for Television Timebase Circuits—D. J. Howlett and L. Buduls. (*Proc. IRE, Aust.*, vol. 19, pp. 680–689; November, 1958.) Noise limiting and AGC circuits are discussed and details are given of an improved form of the heptode sync separator described by Marks (252 of 1953).

621.397.621.2 3121
Some Aspects of Synchronization in Television Receivers—J. van der Goot. (*Proc. IRE, Aust.*, vol. 19, pp. 690–706; November, 1958.) A discussion of scanning oscillators and AFC systems.

621.397.621.2 3122
The Synchronization Separator—an Unexpected Observation—J. Goldthorp. (*Proc. IRE, Aust.*, vol. 19, pp. 706–707; November, 1958.) A note describing the improved performance obtained using a remote-cutoff pentode as composite sync separator in place of a valve with sharp cutoff.

621.397.621.2 3123
Improvements in Television Receivers: Part 5—Stabilization of Line and Frame Output Circuits—B. G. Dammers, A. G. W. Uitjens, A. Boekhorst and H. Heyligers. (*Electronic Applic.*, vol. 18, pp. 129–142; November, 1958.) Detailed descriptions are given of circuits suitable for a 110° cathode-ray tube. Line output stages with flyback ratios of 16, 18 or 21 per cent have been stabilized by voltage-dependent resistors (see Part 4: 989 of March). The frame output stage derives its charging voltage from the stabilized boost voltage. A protective circuit to limit beam current is described.

621.397.621.2 3124
Improvements in Television Receivers: Part 6—Design Considerations for Stabilized Line Output Circuits—B. G. Dammers, A. Boekhorst and D. Hoogmoed. (*Electronic Applic.*, vol. 18, pp. 143–157; November, 1958.) Essential formulas and graphs are given for a quantitative investigation of circuits in which the line output valve operates above the knee of the *Ia/Ya* characteristic. For practical circuits see 3123 above.

621.397.621.2:535.623:621.385.832 3125
Errors of Magnetic Deflection: Part 2—J. Haantjes and G. J. Lubben. (*Philips Res. Rep.*, vol. 14, pp. 65–97; February, 1959.) Approximate formulas for the design of deflection coils have been developed from a theoretical study [Part 1: 2990 of 1957]. Convergence errors in the shadow-mask tube and in an experimental tube with three guns vertically in line are discussed. For the latter tube a deflection coil can be designed which makes dynamic convergence unnecessary.

621.397.621.2:621.373.444.1:621.314.7 3126
Transistor Line Deflection Circuits for Television—P. B. Helsdon. (*Marconi Rev.*, vol. 22, pp. 38–70; 1st Quarter, 1959.) The shunt diode circuit and the retrace-driven circuit due to Guggi (2382 of 1957) are analyzed and their limitations discussed. A flyback-driven circuit is described with automatic phase control, and reverse base current drive to the shunt diode circuit. The output is sufficient for scanning a 70° picture tube.

621.397.621.2:621.385.832 3127
A New Approach to Short Picture-Tube Design—G. A. Burdick. (*Sylvania Technologist*, vol. 12, pp. 2–5; January, 1959.) A brief description of the construction and principle of operation of the tripotential focus (TPF) gun which can be focused by varying the potential to any one of the three elements.

621.397.621.2:621.385.832.032.269.1 3128
A New Electron Gun for Picture Display with Low Drive Signals—K. Schlesinger. (*J. Telev. Soc.*, vol. 9, pp. 15–25; January–March, 1959.) High control sensitivity required for transistor drive is achieved by a new electron-optical approach. Beam focusing and modulation are effected in a cylindrical cavity by two separate electrostatic fields: one of circular symmetry for focusing, and one of transverse-plane geometry for modulation.

621.397.7 3129
ABN Television Transmitter—F. M. Shepherd. (*Proc. IRE, Aust.*, vol. 19, pp. 609–614; November, 1958.) A brief description of main and standby equipment at Gore Hill.

621.397.7 3130
The ATN Television Centre—M. H. Stevenson. (*Proc. IRE, Aust.*, vol. 19, pp. 614–621; November, 1958.) A general description of the center which is near Sidney. Factors which influenced its design and the provisions made for expansion are discussed.

621.397.7:535.623 3131
Holding Video Level while Switching Studios—J. O. Schroeder. (*Electronics*, vol. 32, pp. 96–98; May 29, 1959.) An automatic circuit designed to compensate for wide variations in color or monochrome input signal levels and to maintain a constant output level.

621.397.7:621.396.65 3132
Equalization of Aural and Visual Delay—I. Kerney and W. D. Mischler. (*Bell Lab. Rec.*, vol. 37, pp. 182–186; May, 1959.) The delay of audio signals relayed by coaxial cable relative to video signals relayed by microwave link is reduced by bypassing demodulating equipment at coaxial relay points.

621.397.7:621.396.677.81 3133
The Passive TV Relay and its Practical Possibilities—Aschen. (See 2851.)

621.397.8 3134
Echo Phenomena in Television Images—J. Polonsky, L. Amster and G. Melchior. (*J. Telev. Soc.*, vol. 9, pp. 2–14; January/March, 1959.) English version of 283 of 1957.

621.397.8 3135
Results of Investigations on the Recognizability of Small Details on a Television Screen—F. Below, W. Kroebel and H. Springer. (*Z. angew. Phys.*, vol. 10, pp. 277–285; June, 1958.) An objective method of measuring detail recognition is described based on the use of Landolt-ring test pictures (see 3321 of 1957.) The effects of bandwidth limitation and contrast are investigated.

621.397.8 3136
The Perceptibility of Image Details in Television Images—W. Kroebel, F. Arp and H. Baurmeister. (*Z. angew. Phys.*, vol. 10, pp. 320–327; July, 1958.) The test described in 3138 below is applied to television images. Results are closely related to those obtained with optically projected images.

621.397.8 3137
Phase Shift Considerations in Television Broadcasting and Reception—M. W. Davies. (*Proc. IRE, Aust.*, vol. 19, pp. 642–651; November, 1958.) A general description of phase distortion and of the effects this distortion can have on the received signal of a vestigial-sideband system. Methods available for compensation are discussed; see, *e.g.*, 3117 above.

621.397.8:535.7 3138
The Visual Properties of the Human Eye as a Contribution to the Problem of Assessing the Quality of Projection and Television Images—W. Kroebel, F. Arp and H. Baurmeister. (*Z. angew. Phys.*, vol. 10, pp. 309–317; July, 1958.) A test is described for the quantitative assessment of the perception of small objects by the eye and a mathematical expression is derived relating perception to contrast and object size. For the underlying statistical considerations see *ibid.*, pp. 317–320 (Arp).

621.397.811:621.396.822 3139
Effects of Noise in Television Transmission—T. Kilvington. (*J. Telev. Soc.*, vol. 9, pp. 26–31; January–March, 1959.) The nature of random noise and its effect on sound and vision reception are reviewed. The subjective effects on the picture of both random and periodic noise are described and methods of minimizing them are considered.

621.397.8:621.396.822 3140
Theoretical and Experimental Characteristics of Random Noise in Television—R. Fatehchand. (*J. Brit. IRE*, vol. 19, pp. 335–344; June, 1959.) The characteristics of noise distributed uniformly over the frequency band and that concentrated at the high frequency end of the pass band are compared. The effects of a nonlinear transfer characteristic on noise alone and on noise plus signal are studied, and the relation between these effects and noise visibility on a picture tube is examined.

TRANSMISSION

621.396.61:629.19 3141
Minimum Transmitter System Weight for Space Communications—R. S. Davies and C. S. Weaver. (PROC. IRE, vol. 47, pp. 1151–1152; June, 1959.) A method is given for calculating optimum transmitter weight and antenna size.

621.396.71 3142
New Radio Transmitters at Ongar—(*Engineer, London*, vol. 207, p. 339; February 27, 1959.) Operational data are given on the seven new radio telegraphy transmitters of the British Post Office.

TUBES AND THERMIONICS

621.314.63 3143
The D.C. and A.C. Characteristics of Point-Contact Diodes—H. Beneking. (*Z. angew. Phys.*, vol. 10, pp. 216–225; May, 1958.) A *p-n* diode of spherical symmetry [see, *e.g.*, 2411 of July (Hofmeister and Groschwitz)] is investigated by analogy with calculations for the plane configuration (1398 of April). An interpretation of the injection mechanism of point contacts is obtained. Good agreement between measured and theoretical diode characteristics is found.

621.314.63:621.318.57 3144
Millimicrosecond Switching Diodes—J. Halpern and R. H. Rediker. (*Electronics*, vol. 32, pp. 66–67; June 5, 1959.) Describes briefly the construction of Ge-In-Sb diffusion diodes for switching speeds of 2–3 mμsec (see 2909 of 1958.) A method of measuring the reverse recovery time is outlined.

621.314.63:621.372.632 3145
Transmitting Frequency Converter in which Gold- or Silver-Bonded Diode is Used—S. Kita, H. Sanpei and T. Okajima. (*Rep. elect. Commun. Lab., Japan*, vol. 6, pp. 415–420; November, 1958.) More than 8-db conversion gain with output frequency 4130 mc has been obtained using nonlinear-capacitance Ge diodes [see PROC. IRE, vol. 46, p. 1307, June, 1958 (Kita)].

621.314.63+621.314.7]-71(083.57) 3146
Taking the Heat off Semiconductor Devices—W. Luft. (*Electronics*, vol. 32, pp. 53–56; June 12, 1959.) Charts and nomograms are given for the design of cooling fins.

621.314.7+621.314.63 3147
Transistors and Associated Semiconductor Devices—R. G. Hibberd. (*Proc. IEE*, Part B, vol. 106, pp. 264–278; May, 1959.) Progress in the manufacture and application of these devices is reviewed. Characteristics of many available types are tabulated.

621.314.7 3148
Diffusion Capacitance in Transistors—K. Böke, J. B. M. Spaapen and N. B. Speyer. (*Philips Res. Rep.*, vol. 14, pp. 111–122; April, 1959.) Calculations taking into account the influence of the second junction are in agreement with the results of capacitance measurements at different temperatures, voltages and frequencies.

621.314.7 3149
A Particular Problem of Temperature Distribution concerning the Theory of Junction Transistors—A. Pignedoli. (*R. C. Accad. naz. Lincei*, vol. 23, pp. 257–262; November, 1957.) The temperature distribution as a function of position and time is analyzed for a cylinder of circular or elliptical cross-section; the solution is applicable to the investigation of temperature distribution in a transistor whose junction temperature is raised.

621.314.7:546.28:621.317.3 3150
The Measurement of the Temperature Dependence of the Mobility and Effective Lifetime of Minority Carriers in the Base Region of Silicon Transistors—D. M. Evans. (*J. Electronics Control*, vol. 6, pp. 204–208; March, 1959.) The mobility of holes in the base of a fusion-alloy *p-n-p* transistor was found to vary with the absolute temperature T as $T^{-2.1}$; the corresponding result for electrons in the base of a grown-junction *n-p-n* transistor was $T^{-2.5}$. Results for the effective lifetime of minority carriers in the base are also given.

621.314.7:621.317.7 3151
A Transistor Characteristic Curve Tracer—Young. (See 3060.)

621.314.7:621.385.4 3152
Theory and Use of Field-Effect Tetrodes—H. A. Stone, Jr. (*Electronics*, vol. 32, pp. 66–68; May 15, 1959.) Characteristics and circuit applications of the device are discussed and a description is given of a technique by which laboratory models have been constructed.

621.314.7.012.8 3153
Transmission-Line Analogue of a Drift Transistor—J. te Winkel. (*Philips Res. Rep.*, vol. 14, pp. 52–64; February, 1959.) A method based on a constant drift field is described. Its purpose is to derive base transport parameters and the small-signal equivalent circuit without solving the differential equations explicitly.

621.314.7.012.8 3154
Three-Dimensional Electric-Circuit Model of the High-Frequency Phenomena in a Junction Transistor—G. Brouwer. (*Philips Res. Rep.*, vol. 14, pp. 132–142; April, 1959.) The linearized problem, corresponding to small-signal operation of a transistor, is solved with the aid of a model.

621.383.27 3155
New Photoelectron Multipliers—N. S. Khlebnikov. (*Izv. Ak. Nauk SSSR*, vol. 22, pp. 70–77; January, 1958.) Five types of photomultiplier are briefly described. Typical field distributions and electron paths are illustrated and operating characteristics are tabulated.

621.383.27 3156
Manufacture of Photoelectron Multipliers and Their Basic Parameters—A. E. Melamid. (*Izv. Ak. Nauk SSSR*, vol. 22, pp. 78–82; January, 1958.)

621.383.42 3157
The Open-Circuit Electromotive Force of a Selenium Photocell at Low Temperatures—G. Blet. (*J. Phys. Radium*, vol. 19, pp. 166–169; February, 1958.) Assumptions concerning the internal mechanism of photocells are checked and a general expression, independent of photocell size, is given.

621.383.5 3158
Photovoltaic Effect in Se Photocells having Artificial Intermediate Layers of CdSe, CdTe, ZnSe and ZnTe—H. Tubota and H. Suzuki. (*J. Phys. Soc. Japan*, vol. 14, pp. 38–40; January, 1959.)

621.385.029.6 3159
International Convention on Microwave Valves—(*Proc. IEE*, Part B, vol. 105, supplement no. 11, pp. 609–812; 1958.) The text is given of the following papers which were included among those read at the IEE Convention held in London May 19–23, 1958. Others are abstracted separately. For titles of papers included in supplement no. 10 see 2788 and 2800 of August.

Technology:

1) **A new Ceramic Waveguide Window for Use on *X*-Band Valves**—W. F. Gibbons and A. V. Whale (pp. 609–613.)

2) **Photo-etching Molybdenum Foil**—H. A. C. Hogg (pp. 614–616.)

3) **High-Power Windows at Microwave Frequencies**—J. V. Lebacqz, J. Jasberg, H. J. Shaw and S. Sonkin (pp. 617–622).

4) **Study of the Lives of Dispenser-Type Barium-Tungsten Cathodes**—T. Hashimoto (p. 622).

5) **Application of Discharge Machining to Millimetre-Wave Magnetrons**—M. Nishimaki and T. Asaba (p. 623).

Space-Charge Waves:

6) **Large-Signal Linear-Beam Tube Theory**—C. C. Wang (pp. 624–632).

7) **A Variation Principle for Small-Amplitude Disturbances of Electron Beams**—P. A. Sturrock (pp. 632–634).

8) **Space-Charge Waves on Annular Beams in Drift Tubes**—A. H. W. Beck and P. E. Deering (pp. 635–641).

9) **Magnetic Oscillations in Electron Beams**—R. H. C. Newton (pp. 642–644).

10) **Microwave Amplification using an Unstable Electron Beam in Crossed Electric and Magnetic Fields**—D. J. Harris (pp. 645–648).

Semi-conductors and New Methods of Generation:

11) **Parametric Amplification of Space-Charge Waves**—A. Ashkin, T. J. Bridges, W. H. Lousell and C. F. Quate (pp. 649–651). See 1025 of March.

12) **Some Proposals for Generating High-Frequency Electromagnetic Waves using the Doppler Effect**—R. B. R. Shersby-Harvie (pp. 652–655).

13) **Fast-Wave Interactions with an Electron Film at Cyclotron Resonance**—A. Karp (pp. 656–661).

14) **Junction Diodes in Microwave Circuits**—A. Uhlir (p. 661).

15) **Theory of the Microwave Crystal Mixer**—C. Baron (pp. 662–664).

16) **Microwave Amplification by means of Intrinsic Negative Resistances**—E. Rostas and F. Hülster (pp. 665–673).

Resonators and Slow-Wave Structures:

17) **Dielectric Loading for U.H.F. Valves**—G. B. Walker (pp. 717–718).

18) **A Structure, using Resonant Coupling Elements, suitable for a High-Power Travelling-Wave Tube**—A. F. Pearce (pp. 719–726).

19) **Results on Delay Lines for High-Power Travelling-Wave Tubes**—P. Palluel and J. Arnaud (pp. 727–729).

20) **Theoretical Investigation of some Closed Delay Structures for High-Power Travelling-Wave Tubes**—F. Sellberg (pp. 730–735). Discussion (pp. 735–736).

21) **A New Type of Slow-Wave Structure for Millimetre Wavelengths**—E. A. Ash (pp. 737–745).

22) **Multiple Ladder Circuits for Millimetre Wavelength Tubes**—R. M. White, C. K. Birdsall and R. W. Grow (p. 746). Discussion (p. 746).

23) **Dispersion Curves for a Helix in a Glass Tube**—D. T. Swift-Hook (pp. 747–755).

24) **Some Aspects of the Design of a Helical Coupler for a Travelling-Wave Tube Operating in the 2-Gc/s Band**—P. A. Lindsay and K. D. Collins (pp. 756–761).

25) **Modified Transmission-Line Couplers for Helices**—E. A. Ash and J. D. Pattenden (pp. 762–768).

26) **The Coupling of Three Coaxial Helices**—B. Minakovic (pp. 769–778). Discussion (pp. 778–779).

27) **Characteristics of Interdigital Circuits and their Use for Amplifiers**—J. Hirano (pp. 780–785).

Noise:

28) **Calculations concerning the Noisiness of a Drifting Stream of Electrons**—J. R. Pierce (pp. 786–789).

29) **Progress in Low-Noise Microwave Tube Design**—W. R. Beam. (pp. 790–795).

30) **Frequency Noise in Travelling-Wave Tubes**—R. Liebscher and R. Müller (pp. 796–799).

31) **Noise in Backward-Wave Oscillators**—N. W. W. Smith (pp. 800–804).

32) **Oxide Cathodes for Low-Noise Travelling-Wave Tubes**—E. Windsor (pp. 805–809).

621.385.029.6 3160

Kinetic Theory of Space-Charge: Part 2—Electron Collisional Damping in the Magnetron (and Diode)—L. Gold. (*J. Electronics Control*, vol. 6, pp. 209–235; March, 1959.) A detailed analysis of the part played by scattering in determining the field and charge distribution in a planar diode or magnetron. Various combinations of magnetic field, scattering frequency and transit time are considered. Part 1: 3696 of 1957.

621.385.029.6 3161

A. C. Operation of Continuous-Wave Magnetrons—W. Schmidt. (*Electronic Applic.*, vol. 18, pp. 158–162; November, 1958.) English version of 4013 of 1958.

621.385.029.6 3162

Current Limitation of A.C.-Operated Continuous-Wave Magnetrons by means of Inductance—E. G. Dorgelo. (*Electronic Applic.*, vol. 18, pp. 163–170; November, 1958.) Adjustment of the angle of flow, combined with high efficiency, can be achieved using a supply unit of low resistance incorporating an inductance of suitable value in the form of stray inductance or a choke.

621.385.029.6 3163

A Proposed Ferrite-Tuned Magnetron—A. Singh and R. A. Rao. (*J. Inst. Telecommun. Engrs., India*, vol. 5, pp. 72–76; March, 1959.) The frequency of an inverted interdigital magnetron can be controlled by varying a biasing magnetic field applied to a ferrite cylinder placed near the shorted end of a coaxial line, which is coupled to the interdigital resonator. A tuning range of 5–10 per cent may be expected as shown by a theoretically evaluated tuning curve.

621.385.029.6:621.372.8 3164

Backward-Wave Oscillations in an Unloaded Waveguide—R. H. Pantell. (PROC. IRE, vol. 47, pp. 1146; June, 1959.) Using a system in which electrons travel in a helical beam in ordinary *S*-band waveguide, oscillations have been observed in the range 2.5–4 kmc at a power level of 0.4 watt.

621.385.029.6:621.396.822 3165

An Experimental Study of Interception Noise in Electron Streams at Microwave Frequencies—B. A. McIntosh. (*Can. J. Phys.*, vol. 37, pp. 285–299; March, 1959.) The frequency used was 3 km. An electron beam was produced in a demountable vacuum system by a parallel-flow Pierce gun in a confining magnetic field. A series of circular apertures and mesh grids on a plate capable of being moved within the vacuum chamber intercepted various fractions of the beam current. The excess noise caused by interception was measured at the anode of the electron gun and at various points in a drift region. Interception noise caused by mesh grids was much greater than that caused by circular apertures.

621.385.032.213.13:538.632 3166

Hall Effect in Oxide Cathodes—T. Yabumoto. (*J. Phys. Soc. Japan*, vol. 14, pp. 134–139; February, 1959.) The apparent electron mobility in the range 700°K–1200°K was about 10^3–10^4 cm²/v sec which is very high as compared with the values obtained for single crystals. The pore conduction hypothesis is discussed.

621.385.1:621.3.049.7 3167

Thermionic Integrated-Micromodules—Beggs, Grattidge, Molenda, Haase and Dickerson. (See 2863.)

621.385.1:621.314.7:621.373.43 3168

Tube-Transistor Hybrids Provide Design Economy—Dunn and Hekimian. (See 2877.)

621.385.1:621.317.61 3169

A Method for the Accurate Measurement of Mutual Conductance of Thermionic Valves—Child and Sargent. (See 3059.)

621.385.1.012.7 3170

The Mu of Ordinary Receiving Tubes—G. D. O'Neill. (*Sylvania Technologist*, vol. 11, pp. 125–132; October, 1958.) A distinction is made between the electronic mu and the electrostatic mu. A new formula is given for mu in terms of electrode dimensions; it is simple to evaluate and more accurate than others which are available.

621.385.832:621.397.62 3171

Design of a Flat Rectangular C.R. Tube—W. R. Aitken. (*Electronic Equip. Engrg.* vol. 6, pp. 24–28; December, 1958.) A qualitative description with a note on operating experience. See 977 of 1958 for detailed analysis.

621.385.832:621.397.621.2:535.623 3172

Errors of Magnetic Deflection: Part 2—Haantjes and Lubben. (See 3125.)

621.385.832.032.36 3173

Energy Losses of Cathode Rays at Binder Films of the Phosphor Screens of Cathode-Ray Tubes—G. Gergely and I. Hanges. (*Z. angew. Phys.*, vol. 10, pp. 225–228; May, 1958.) Measurements of light emission were made on a number of phosphor screens with colloidal binder films of differing composition and thickness, to determine the dependence of losses on electron energy and film characteristics.

621.387 3174

The Effect of Trigger Pulse Polarity on the Anode Breakdown Time of the Cold-Cathode-Arc Conduction Tetrode—R. Feinberg. (*J. Electronics Control*, vol. 6, pp. 246–257; March, 1959.) The breakdown time is found to depend on the trigger pulse duration if this pulse is positive, but not if it is negative. The explanation of this result is discussed.

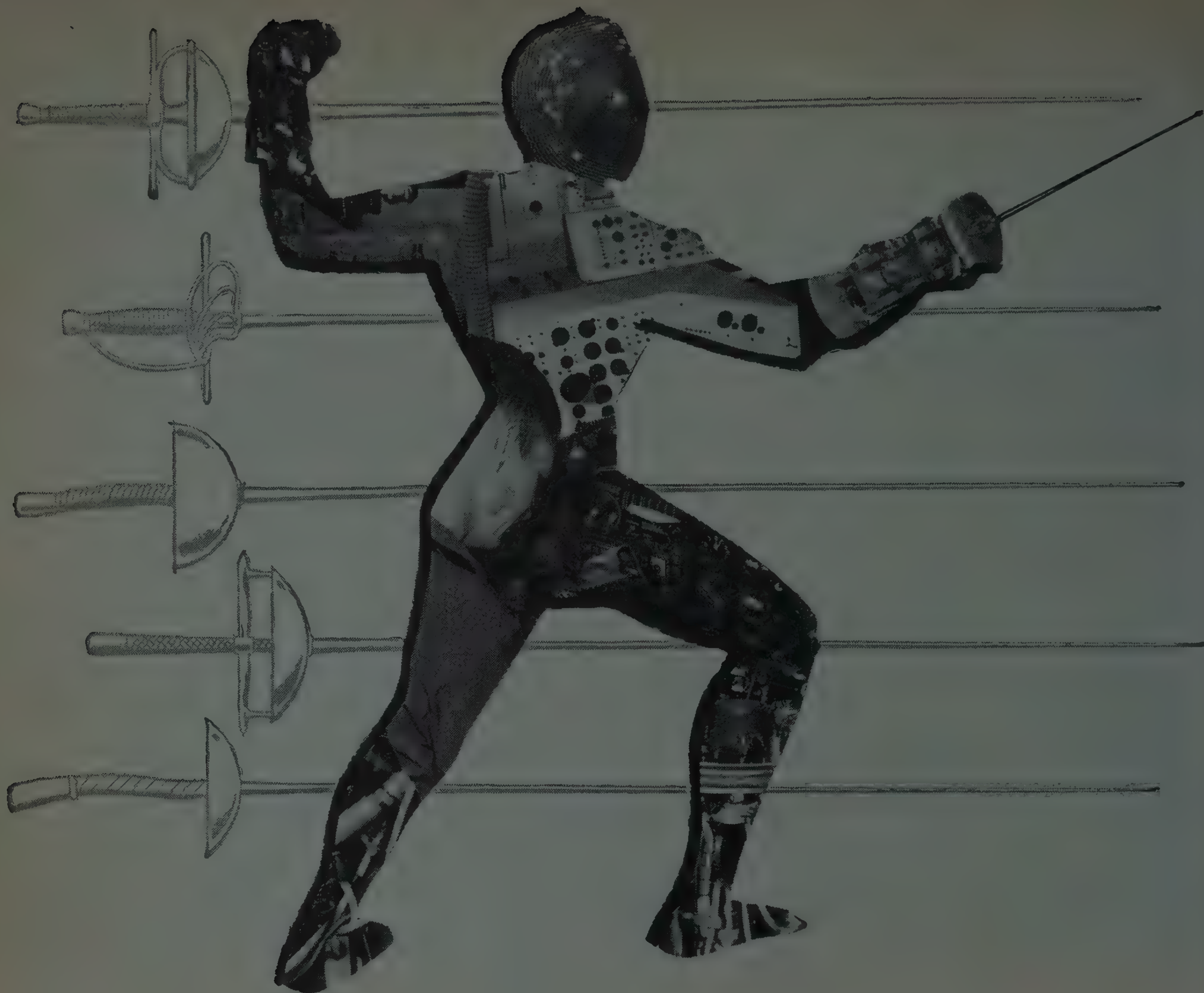
MISCELLANEOUS

621.3.029.6 3175

Report of Advances in Microwave Theory and Techniques—1957—R. E. Beam. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 251–263; July, 1958.) 320 references.

621.37/.39(81) 3176

Electronics and Communications in Brazil—J. I. Caicoya. (*Brit. Commun. Electronics*, vol. 6, pp. 364–370; May, 1959.) Gives details of manufacturing and research organizations.



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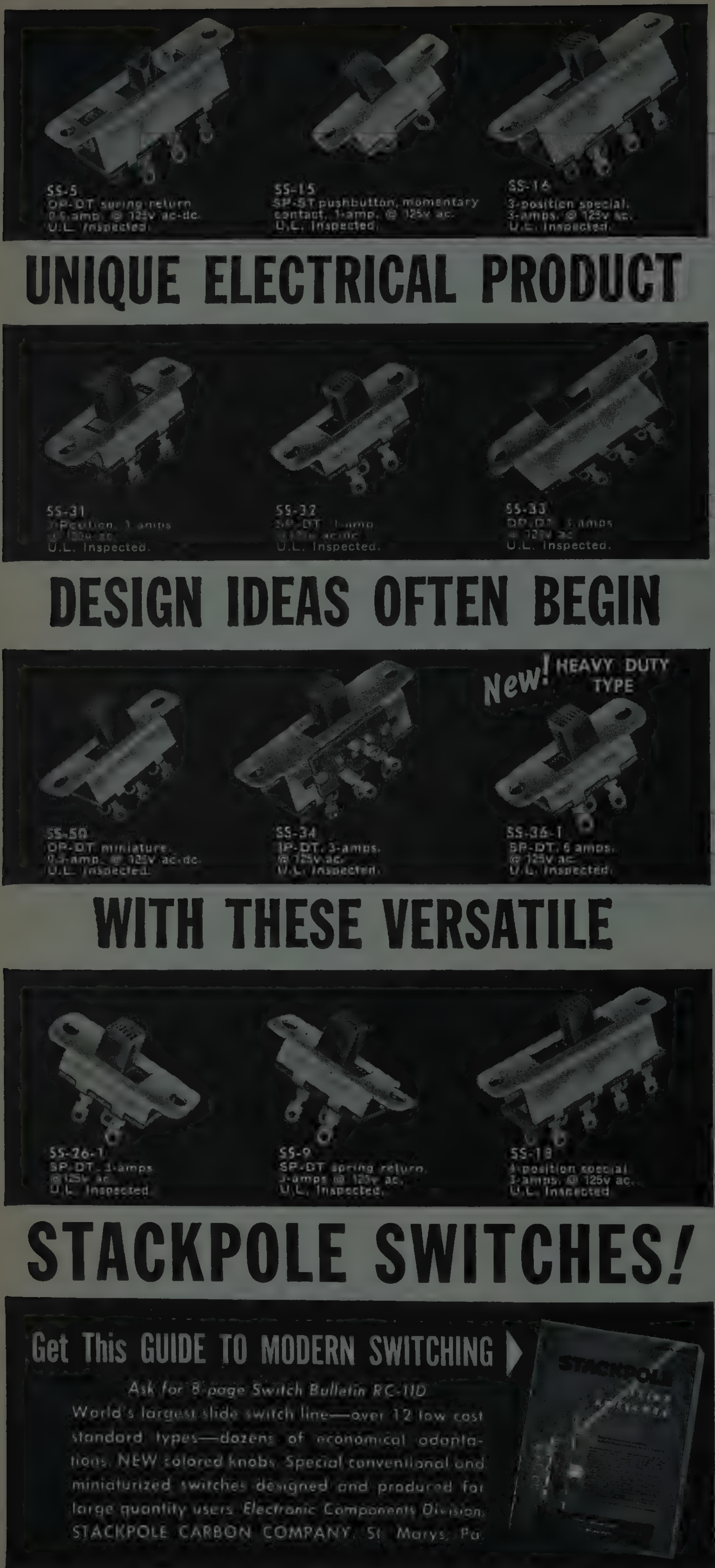

Professional Group Meetings

Audio

Syracuse—May 19

"Stereo Components,"—(phono cartridge), P. E. Pritchard, General Electric Co.

"Stereo Components,"—(speaker systems), A. F. Petrie, General Electric Co.

Automatic Control

Los Angeles—June 9

"Synthesis and Analysis of Bridged-T Networks Using Root-Locus Techniques," T. A. Savo, Hughes Aircraft Co.

Broadcasting

San Francisco—May 5

"Seminar to Discuss Methods of Measurements of TV Broadcast Systems," H. Brown, KGO-TV, San Francisco; D. Anderson, KRON-TV, San Francisco; H. Dover, RCA Broadcast Field Engineer.

Component Parts

Los Angeles—June 8

Panel Discussion, "Reducing the Cost of Component Part Reliability Assurance," R. F. Edwards, M. Barbe, B. Hecht, A. Felden, H. B. Brunswick, L. W. Perverill, J. J. Tonsen, J. Thresh.

Electronic Computers

San Francisco—June 16

"Four-layer Diodes and Their Possible Role in Digital Devices," W. Shockley, Beckman Instruments Inc.

Engineering Management

Los Angeles—July 1

"A New Format for Electronics Financing," R. T. Silberman, Electronics Capital Corp.

Los Angeles—April 6

"Big Unionism and Big Management," J. Van de Water, UCLA.

Twin Cities Chapter—May 27

"Hows and Whys of Management Planning," H. E. Weyrauch, Maico Electronics.

Twin Cities Chapter—March 10

"The Shift from Engineering to Management," W. E. Foeste, Telex Inc.

Twin Cities Chapter—November 6

"Can Engineers be Effective Managers," H. Mold, Minneapolis-Honeywell.

(Continued on page 108A)

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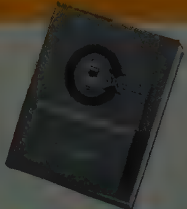

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Professional Group Meetings

(Continued from page 104A)

Medical Electronics

Omaha-Lincoln—June 19

"International Symposium on Blood Flowmeters," summaries by moderators: Drs. Feder, Olmsted, Spencer, Brecher, Fry, J. Herrick and G. M. Servelius.

Omaha-Lincoln—June 17

"International Symposium on Blood Flowmeters," 10 Papers, 9 Demonstrations, 3 Discussion Groups.

Microwave Theory and Techniques

Long Island—May 26

"Traveling Wave Parametric Amplifiers," R. Engelbrecht, BTL.

Los Angeles—June 11

"Relativity, Atomic Clocks, Light, and Satellites," H. Lyons, Hughes Aircraft Co.

Los Angeles—May 14

"Status of Antenna & Microwave Development at SRI," S. Cone, Stanford Res. Inst.

(Continued on page 110A)

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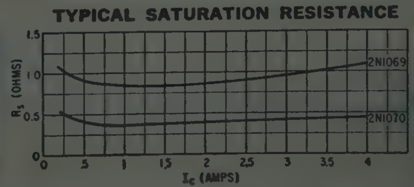

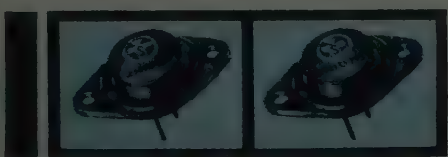

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Professional Group Meetings

(Continued from page 108A)

Reliability and Quality Control

San Francisco—May

"Environmental Test Facilities Lockheed Missile & Space Division," R. Bumstead, Lockheed Missile and Space Div.

San Francisco—February 18

All Day Seminar

San Francisco—January 27

"Testing Operations on Limited Production Electronics," W. Rolly, Ampex Corp.

Vehicular Communications

Los Angeles—May 13

"Performance Budgeting of Municipal Mobile Radio Systems," E. Simon, San Diego City Public Works Dept

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(Continued on page 112A)

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(Continued from page 110A)

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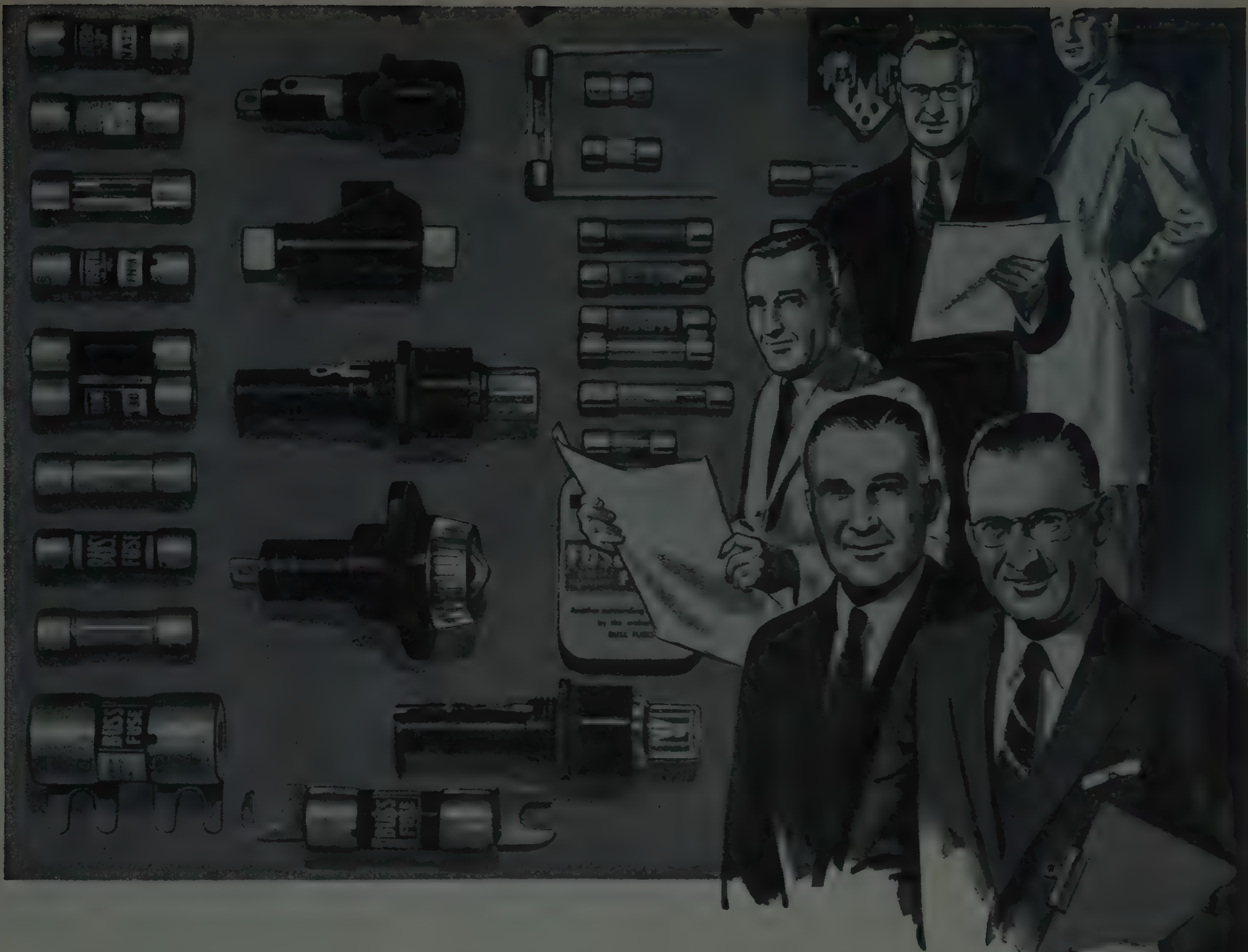
(Continued on page 114A)



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Capasso, G. F., Kingston, N. Y.
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Cilluffo, J. S., Plainview, L. I., N. Y.
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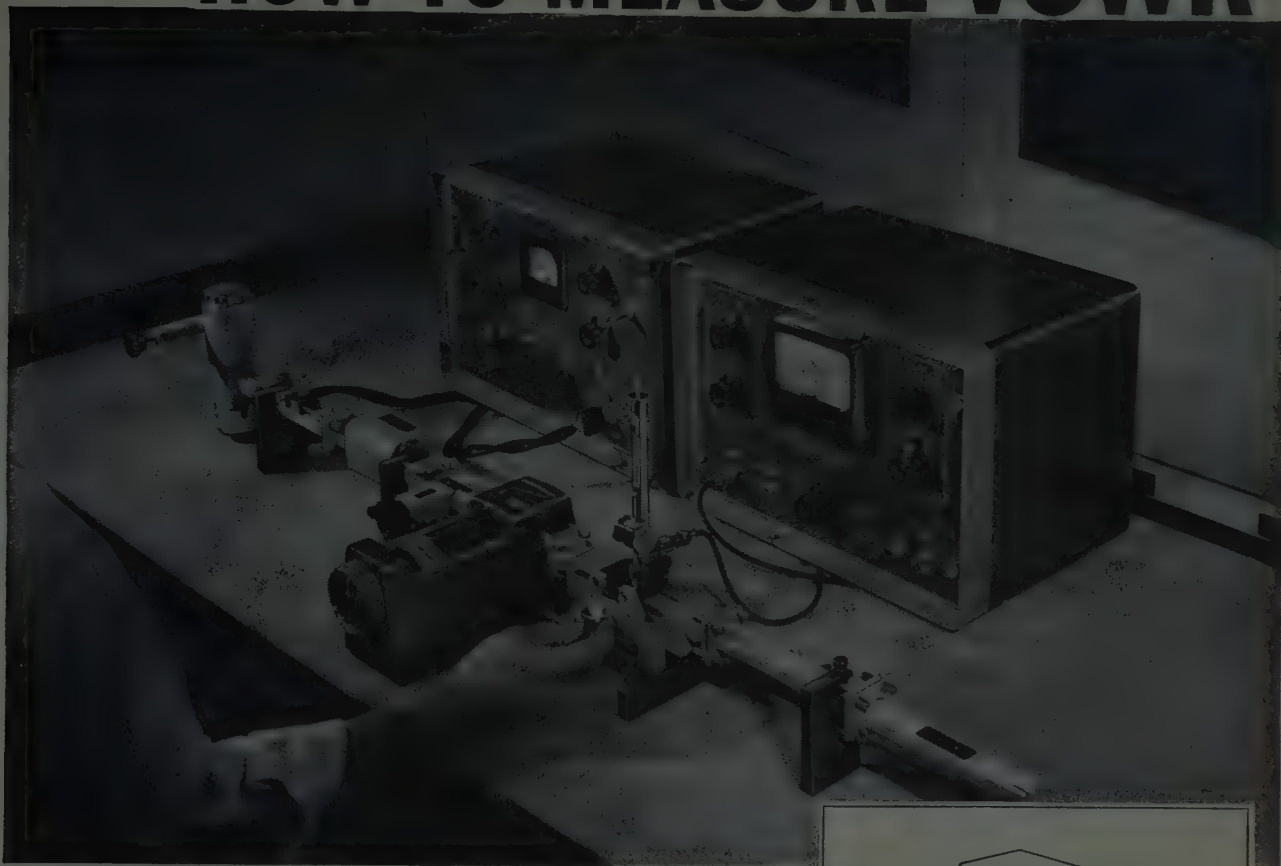
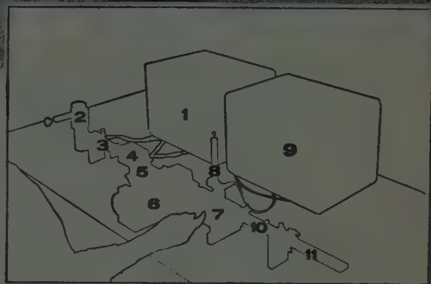
(Continued on page 118A)

HOW TO MEASURE VSWR





This microwave measurement bench is for the determination of Voltage Standing Wave Ratio using the slotted-line technique. Other systems utilizing directional couplers or magic tees for measurement of VSWR are known, but the use of the Slotted Section assures maximum accuracy.

Regardless of the technique used, accurate readings depend on the precision of the test instruments involved. When it comes to microwave test instruments PRD produces the widest range of the most precise equipment available anywhere in the world.

You will notice in the measurement bench shown that there are four test components separating the klystron tube mount from the Slotted Section. These are: A Slide Screw Tuner, ferrite Isolator, Level Set Attenuator, and a broadband direct reading Frequency Meter. THE USE OF THESE FOUR COMPONENTS IN THE TEST LINE IS MANDATORY FOR PRECISE VSWR MEASUREMENTS!

The reason for this is clear when you consider the interrelationship between VSWR, power, and frequency.

The Slide Screw Tuner is used to match the klystron output to that of the tandem test line, thereby maximizing its output and increasing its stability.

The use of the ferrite Isolator assures klystron frequency and power stability by shielding the source generator from changes in impedance further down the line. It accomplishes this with negligible attenuation of the incident power. The Level Set Attenuator is used to adjust the amount of power feeding the remainder of the test line.

The reaction Frequency Meter accurately monitors the output of the klystron by a resonant dip on the Standing Wave Amplifier.

A Slotted Section, tuned Broadband Probe, Standing Wave Amplifier, and matched Termination complete the precision waveguide, X-band, VSWR bench. A Klystron Power Supply to provide the signal source with power and modulation and a Fixed Waveguide Attenuator to simulate the unknown are also shown.

Special problems in VSWR and other related measurements? — Contact our Applications Engineering Department.

We at PRD have pioneered the development of precision microwave test instruments . . . PRD is the only pioneer company today producing microwave test instruments exclusively. In fact, we're just about the largest microwave company in the world . . . our cable address is MICROWAVE, New York, USA.

For technical details and specifications covering products shown write:

TEST INSTRUMENTS USED IN THIS X-BAND VSWR BENCH

1—809 Klystron Power Supply, catalog page F-10
2—703 Shielded Tube Mount, catalog page F-8
3—303-A Slide Screw Tuner, catalog page B-14
4—1203 Isolator, catalog page A-21
5—159-A Level Set Attenuator, catalog page A-17
6—535 Frequency Meter, catalog page D-12
7—203-D Slotted Section, catalog page B-11
8—250-A Broadband Probe, catalog page B-12
9—277-A Standing Wave Amplifier, catalog page E-7
10—UNKNOWN—represented by a 140 Fixed Waveguide Attenuator, catalog page A-11
11—116-A Waveguide Termination, catalog page A-19

MICROWAVE ENGINEERS-SCIENTISTS
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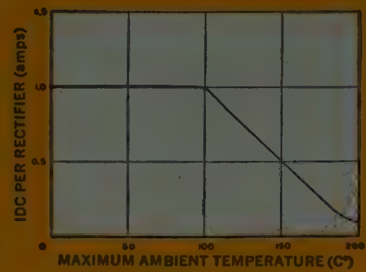
. . . designed to meet ALL your circuit requirements: current, voltage, temperature, size . . . now available from Transitron.

A complete description of the lead and stud mounted types, which are summarized below, is in bulletin TE-1351.

We welcome your inquiries concerning special requirements such as high frequency, fast recovery and high voltage applications.

MIDGET RECTIFIER
1 AMP @ 100°C



Transitron announces, higher ratings and *smaller* size in a lifetested lead mounted silicon rectifier. By establishing a high level of designed quality, these rectifiers feature reliable 200°C operation. Remember, the size is SMALLER, the flange is GONE! These units will meet all electrical and environmental requirements of the JAN-1N 547 series.

Type	Peak Recurrent Inverse Voltage (Volts)	Maximum Average Forward Current @ 200°C (Milliamps)	Maximum Average Forward Current @ 100°C (Amps)	Maximum Forward Voltage @ 25°C (Volts) (Milliamps)
TK61	600	100	1.0	1.0 @ 750
TK41	400	100	1.0	1.0 @ 750
TK21	200	100	1.0	1.0 @ 750

Write for bulletin PB-58

SILICON CONTROLLED RECTIFIER

Handling 10 KW Power

Transitron's Silicon Controlled Rectifier is a PNPN High power bistable controlled switching device. It is analogous to a thyratron or ignitron, with far smaller triggering requirements and microsecond switching. The low forward voltage drop permits high current ratings and provides high efficiency with low cooling requirements. The PNPN design permits higher voltage ratings and lower saturation resistance than power transistors. This permits the smallest packaging for high power control yet made possible.

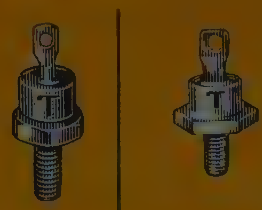
NOW AVAILABLE IN
TRANSITRON'S NEW PACKAGE

Type	Minimum Peak Reverse Voltage (Volts)	Minimum Forward Breakdown Voltage (Volts)	Maximum Average Forward Current (amps) at T case =100°C	Maximum Average Forward Current (amps) at T case =25°C
TCR102	100	100	10	20
TCR202	200	200	10	20
TCR302	300	300	10	20
TCR402	400	400	10	20

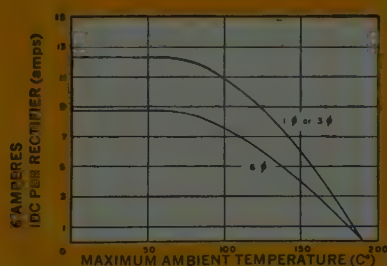
Maximum Storage Temperature Range −65°C to +150°C
Maximum Operating Temperature Range −65°C to +125°C

Send for Bulletin TE-1356A

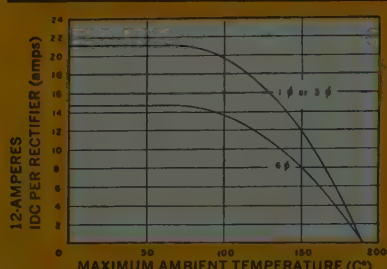
HIGH CURRENT RECTIFIERS



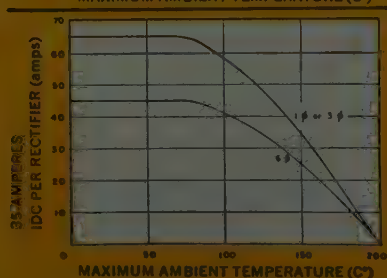
Now, from Transitron, stud-mounted silicon power rectifiers which combine high power handling ability with a minimum of size and weight . . . The extremely low forward resistance and thermal impedance of these units allow operation up to 12 amperes @ 150°C case temperature in the 7/16" hex base configuration, and similarly up to 35 amperes @ 150°C case temperature in the 1 1/16" hex base configuration. Still further, the inherently low leakage currents and high peak inverse voltage ratings allow flexibility in the design of both power supply and magnetic amplifier circuits.



Type	Peak Recurrent Inverse Voltage (Volts)	Maximum Forward Voltage @ 25°C (Volts) @ (Amps)	Maximum Average *Inverse Current 150°C (Milliamps)
TM68	600	1.1 @ 6	2
TM58	500	1.1 @ 6	2
TM48	400	1.1 @ 6	2
TM38	300	1.1 @ 6	2
TM28	200	1.1 @ 6	2
TM18	100	1.1 @ 6	2
TM8	50	1.1 @ 6	2



Type	Peak Recurrent Inverse Voltage (Volts)	Maximum Forward Voltage @ 25°C (Volts)@ (Amps)	Maximum Average *Inverse Current 150°C (Milliamps)
TM69	600	1.2 @ 12	2
TM59	500	1.2 @ 12	2
TM49	400	1.2 @ 12	2
TM39	300	1.2 @ 12	2
TM29	200	1.2 @ 12	2
TM19	100	1.2 @ 12	2
TM9	50	1.2 @ 12	2



Type	Peak Recurrent Inverse Voltage (Volts)	Maximum Forward Voltage @ 25°C (Volts)@ (Amps)	Maximum Average *Inverse Current 150°C (Milliamps)
TR603	600	1.5 @ 100	5
TR503	500	1.5 @ 100	5
TR403	400	1.5 @ 100	5
TF303	300	1.5 @ 100	5
TR203	200	1.5 @ 100	5
TR153	150	1.5 @ 100	5
TR103	100	1.5 @ 100	5
TR53	50	1.5 @ 100	5

*Averaged over one cycle with rectifier operating at full rated current and voltage into a resistance load.

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IMPULSE

A DIGEST OF NEW DEVELOPMENTS IN ELECTRONICS AND AUTOMATION

PUBLISHED BY ROME CABLE CORPORATION, ROME, N. Y.

PIONEERS IN INSTRUMENTATION CABLE ENGINEERING

ELECTRONIC "VOICE" FOR MUTES. Persons who have lost their voices through surgical removal (laryngectomy) or paralysis of their vocal cords should be heartened by the news of an artificial "voice," utilizing electronic parts, that is presently being developed. This artificial larynx—cylindrical in shape, 2 inches in diameter and 3 inches long—is held against the throat to produce a slightly mechanical but highly intelligible sound. User can control pitch, thus giving speech a natural conversational sound not previously obtainable. Frequency can be adjusted to correspond with the normal range of pitch of a woman's voice, when desired. Utilizing the principle of a vibrating transducer, the device consists of a modified telephone receiver and a transistorized pulse generator, and is powered by a battery.

TELEMETRY STATIONS-IN-THE-SKY. Aircraft of one Air Force squadron at the Missile Test Center in Florida act as "flying laboratories" in gathering data from missiles and locating nose cones. Nine of the planes are KC-54's—elaborately instrumented aircraft that are complete telemetry stations in themselves. Instrumentation is the latest and best of its type, giving them multiple capability. They obtain missile mid-course and terminal flight telemetry data, measure re-entry radiation and assist in nose cone recoveries. In addition to the nine JC-54's, this squadron has other planes which have various jobs over the missile range, including simulating cruise missile flights and helping to align ground missile-tracking equipment.

THOSE JAPANESE IMPORTS. Japanese electronic products are being imported in increasing numbers. In the first quarter of this year alone, our imports from Japan were almost four times greater than in the first quarter of 1958—an estimated \$24-32 million of retail business. An increase of 36% of imported transistor and other wireless communications equipment is anticipated for the fiscal year beginning last April 1.

GOT TROUBLES? If you're troubled by equipment-wiring problems, you should consider the record being established by Rome Synthinol 901, a special 105° PVC compound for wire insulation and jacketing. Developed in Rome Cable's laboratory and first introduced in 1949, Rome Synthinol 901 has proved by test and actual use to be superior to conventional PVC compounds in many ways. A new booklet—so new it hasn't even been delivered by our printer yet—describes the properties and uses of this amazing compound. Be the first on your block to own a copy. We'll put your name on the advance-mailing list and send you a free copy as soon as it's available. Drop a line to IMPULSE, c/o Dept. 12-10, Rome Cable Corp., Rome, N. Y.

STATE OF SOVIET ENGINEERING. What is the state of Russian engineering as witnessed at the Soviet Exposition in New York City last July and part of August? Visitors studying the Russian electronic equipment and components at close range noted that most of it would probably meet all applicable JAN-MIL specifications. Modular design was very evident and transistors were widely used, but less use was made of printed circuits than in this country. As a result, transistorized equipment lacked full miniaturization. New circuit ideas? Not many to be seen. If anything, Russian engineers tend to overdesign—putting four stages where a more sophisticated single stage might do the job. But substantial progress was shown in electron-device work—especially traveling-wave tubes and transistors. There was no evidence of integrated or semiconductor solid circuits.

These news items represent a digest of information found in many of the publications and periodicals of the electronics industry or related industries. They appear in brief here for easy and concentrated reading. Further information on each can be found in the original source material. Sources will be forwarded on request. (11)

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(Continued from page 114A)

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(Continued from page 118A)

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(Continued from page 120A)

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Avanessians, A. A., Flushing, L. I., N. Y.
Axel, E. K., Levittown, N. J.
Bailey, T. W., Detroit, Mich.
Baker, H. C., Ottawa, Canada
Banks, B. M., Grapevine, Tex.
Bardelli, F., Roma, Italy
Barstad, S., Seattle, Wash.
Battin, J. W., Addison, Ill.
Bauer, A. S., Chicago, Ill.
Bell, J. R., Beirut, Lebanon
Biaggi, B. E., Washington, D. C.
Bignall, K. E., Ann Arbor, Mich.
Birkemeier, W. P., Fayetteville, Ark.
Black, F. H., Philadelphia, Pa.
Blackburn, E. E., Alexandria, Va.
Brusie, N. C., Dallas, Tex.
Burkitt, G. C., Detroit, Mich.
Burrows, C. W., Jr., Los Angeles, Calif.
Burrows, L. T., Kensington, Victoria, Australia
Byers, H. K., State College, Pa.
Caddes, D. E., Mountain View, Calif.
Chiron, B. P., Paris, France
Clark, D. E., Ventura, Calif.
Clark, J. J., Hoboken, N. J.
Clark, W. M., Jr., Stanford, Calif.
Coleman, D. J., Albuquerque, N. Mex.
Conley, D., Rochester, N. Y.
Coombs, J. S., Bethesda, Md.
Cooper, A. T., Panama City, Fla.
Cooper, A. F., Santa Ana, Calif.
Corkhill, R. E., Wenham, Mass.
Cortesi, A. A., Santa Clara, Calif.
Coubrough, J., Jr., Eglin AFB, Fla.
Crist, L. W., Philadelphia, Pa.
Crutchlow, L. G., Ottawa, Ont., Canada
Currier, J. B., Medinah, Ill.
Davis, R. W., Palo Alto, Calif.
Decker, F. R., Melrose, Mass.
Dubisky, M. J., Cedar Rapids, Iowa
Duell, A. W., San Jose, Calif.
Edwards, M. D., Jr., Merritt Island, Fla.
Elenbaas, A. R., Valkenburg by Leiden, Netherlands
Evans, R. I., Bristol, Gloucestershire, England
Flatters, W. F., Ontario, Calif.
Fouts, W. L., Rome, N. Y.
Fox, J. B., Dallas, Tex.
Frederick, W. C., Springfield, Va.
Froberg, W. E., Maywood, Ill.
Gansenberg, V. G., Foxboro, Mass.
Ginsberg, M. B., Washington, D. C.
Glatt, M. A., Severna Park, Md.
Glow, A. E., Jr., Schenectady, N. Y.
Goodacre, B., Rexdale, Ont., Canada
Goslen, M. B., Kernersville, N. C.

(Continued on page 128A)

Simplified, Accurate Broadband Measurements

Frequency Range 500 KC to 250 MC

BRC Type 250-A RX Meter... Complete, Integrated, Self-contained— No External Units Required

The integral design of this RF bridge eliminates difficulties from leakage, hand effects or improper matching that can occur when several units must be interconnected to make measurements. Integrated within the 250-A are an accurate, continuously tuned RF oscillator, high frequency bridge, amplifier-detector and null indicating meter. Connections to the unknown impedance are arranged for practically zero lead length. Equivalent parallel resistance and capacitance are read directly from the calibrated dials over the entire range.

Typical Applications

The RX meter provides a quick accurate means of measuring the RF resistance and reactance of a wide variety of materials, components and circuits. Measurements can also be made of the dynamic parameters of transistors, vacuum tubes and diodes under selected conditions of D.C. bias and operating levels. Measurements of antennas and antenna systems are readily convertible to series equivalents or VSWR. Transmission line characteristic impedance, attenuation and velocity of propagation are easily determined.

Specifications

Frequency Range: 500 KC to 250 MC

Frequency Accuracy: ±1%

Resistance Range (Rp): 15 to 100,000 ohms (28" scale length)

Resistance Accuracy: $\pm\left[2+\frac{F^*}{200}+\frac{R^*}{5000}+\frac{Q^*}{20}\right]\% + 0.2\,\Omega$

*F = frequency (MC); R = RX Meter Rp reading (Ω);

$Q = \frac{R}{\omega C \times 10^{-12}}$, where C = RX Meter Cp reading ($\mu\mu f$)

Resistance Calibration: Increments of approx. 3% throughout most of range.

Capacitance Range (Cp): 0 to 20 $\mu\mu f$ (0.1 $\mu\mu f$ increments)

Capacitance Accuracy: $\pm (0.5 + 0.5F^{2*}\ C^* \times 10^{-5})\% \pm 0.15\ \mu\mu f$

*F = frequency (MC); C = RX Meter Cp reading ($\mu\mu f$)

Capacitance Calibration: 0.1 $\mu\mu f$ increments.

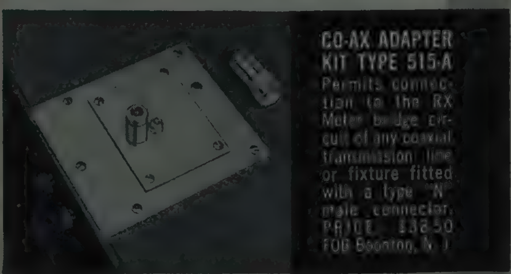
Inductance Range (Lp): .001 μh to 100 mh

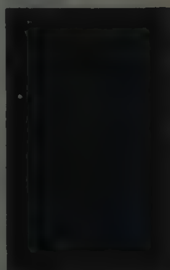
Inductance Accuracy: Basic accuracy is capacitance accuracy given above.

Test Voltage: 0 volts D.C. (50 ma permissible thru unknown terminals)

0.1 to 0.5 volts RF (conveniently reducible to 20 mv)

Price: $1525.00 F.O.B. Boonton, N. J.





25th ANNIVERSARY

Precision Electronic Instruments since 1934

BOONTON RADIO CORPORATION

BOONTON, NEW JERSEY, U.S.A.

Membership

(Continued from page 126A)

Graham, E. A., Jr., Burlington, Mass.
Granville, R. W., Lynbrook, N. Y.
Grey, W. J., Kitchener, Ont., Canada
Haim, H. J., Los Angeles, Calif.
Hartenberg, B., Rio de Janeiro, D.F., Brazil
Heid, J. P., Rosemont, Pa.
Hirsch, S. L., New York, N. Y.
Holloway, T. D., Fort Wayne, Ind.
Howell, R. L., Eau Gallie, Fla.
Hunter, D. R., Mountain View, Calif.
Hwang, C., Hawthorne, Calif.
Iwamura, D. C., China Lake, Calif.
Jeffers, R. E., Sunnyvale, Calif.
Jennings, R. B., Huntsville, Ala.
Jensen, P. W., Mountain View, Calif.
Johnson, H. A., Jr., Corona, Calif.
Johnson, J. M., Jr., China Lake, Calif.
Jones, A. H., Liverpool, England
Kalafut, J. S., Elmira, N. Y.
Keene, D. E., Hagerstown, Md.
Kenrick, A. F., Los Angeles, Calif.
Kovac, J., Jr., Orange, Calif.
Krejny, E. L., Cleveland, Ohio
Krupnik, S., Jr., Milwaukee, Wisc.
Lacy, E. A., Alexandria, Va.
Lawyer, D. S., Los Angeles, Calif.
LeCroissette, D. H., Philadelphia, Pa.
Lee, Y. H., Washington, D. C.
Leeson, J. L., Beloit, Wisc.
Lemestre, R., Los Angeles, Calif.
Leverone, A. A., Norfolk, Mass.
Lewis, F. J., Buffalo, N. Y.
Linn, C. W., Santa Clara, Calif.
Mac Intyre, R. E., Sr., Johnson City, N. Y.
Maiden, C. E., Culver City, Calif.

(Continued on page 130A)

FREQUENCY STANDARDS

PRECISION FORK UNIT
TYPE 50

Size 1" dia. x 3¾" H. Wght., 4 oz.*

Frequencies: 240 to 1000 cycles
Accuracies:—
Type 50 (±.02% at —65° to 85°C)
Type R50 (±.002% at 15° to 35°C)
Double triode and 5 pigtail parts required
Input, Tube heater voltage and B voltage
Output, approx. 5V into 200,000 ohms

*3⅛" high
400 - 1000 cy.

FREQUENCY STANDARD
TYPE 50L

Size 3¾" x 4½" x 5½" High
Weight, 2 lbs.

Frequencies: 50, 60, 75 or 100 cycles
Accuracies:—
Type 50L (±.02% at —65° to 85°C)
Type R50L (±.002% at 15° to 35°C)
Output, 3V into 200,000 ohms
Input, 150 to 300V, B (6V at .6 amps.)

PRECISION FORK UNIT
TYPE 2003

Size 1½" dia. x 4½" H. Wght. 8 oz.*

Frequencies: 200 to 4000 cycles
Accuracies:—
Type 2003 (±.02% at —65° to 85°C)
Type R2003 (±.002% at 15° to 35°C)
Type W2003 (±.005% at —65° to 85°C)
Double triode and 5 pigtail parts required
Input and output same as Type 50, above

*3½" high
400 to 500 cy.
optional

FREQUENCY STANDARD
TYPE 2005

Size, 8" x 8" x 7¼" High
Weight, 14 lbs.

Frequencies: 50 to 400 cycles
(Specify)
Accuracy: ±.001% from 20° to 30°C
Output, 10 Watts at 115 Volts
Input, 115V. (50 to 400 cycles)

FREQUENCY STANDARD
TYPE 2007-6 **NEW**
TRANSISTORIZED, Silicon Type

Size 1½" dia. x 3½" H. Wght. 7 ozs.

Frequencies: 400 — 500 or 1000 cycles
Accuracies:
2007–6 (± .02% at —50° to +85°C)
R2007–6 (±.002% at +15° to +35°C)
W2007–6 (±.005% at —65° to +125°C)
Input: 10 to 30 Volts, D. C., at 6 ma.
Output: Multitap, 75 to 100,000 ohms

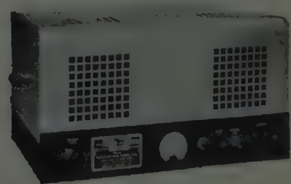
FREQUENCY STANDARD
TYPE 2121A

Size
8¾" x 19" panel
Weight, 25 lbs.
Output: 115V
60 cycles, 10 Watt
Accuracy:
±.001% from 20° to 30°C
Input, 115V (50 to 400 cycles)

FREQUENCY STANDARD
TYPE 2001-2

Size 3¾" x 4½" x 6" H., Wght. 26 oz.

Frequencies: 200 to 3000 cycles
Accuracy: ±.001% at 20° to 30°C
Output: 5V. at 250,000 ohms
Input: Heater voltage, 6.3 - 12 - 28
B voltage, 100 to 300 V., at 5 to 10 ma.



FREQUENCY STANDARD
TYPE 2111C

Size, with cover
10" x 17" x 9" H.
Panel model
10" x 19" x 8¾" H.
Weight, 25 lbs.
Frequencies: 50 to 1000 cycles
Accuracy: (±.002% at 15° to 35°C)
Output: 115V, 75W. Input: 115V, 50 to 75 cycles.

ACCESSORY UNITS
for TYPE 2001-2

L—For low frequencies
multi-vibrator type, 40-200 cy.
D—For low frequencies
counter type, 40-200 cy.
H—For high freqs, up to 20 KC.
M—Power Amplifier, 2W output.
P—Power supply.

This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government departments, armed forces—where maximum accuracy and durability are required.

WHEN REQUESTING INFORMATION
PLEASE SPECIFY TYPE NUMBER

American Time Products, Inc.

Watch Master
Timing Systems

Telephone: PLaza 7-1430

580 Fifth Ave., New York 36, N. Y.

Membership

(Continued from page 128A)

Malinowski, A. B., Washington, D. C.
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Marsh, R. G., Webster Groves, Mo.
Matsuo, M., Osaka, Japan
McCanless, C. P., Oak Ridge, Tenn.
McGowan, R. F., Upper Darby, Pa.
McMurray, C. S., Oak Ridge, Tenn.
Meyer, A. W., Cedar Rapids, Iowa
Meyer, E. E., Kailua, Hawaii
Michel, J. J. A., Manhasset, L. I., N. Y.
Miller, W. S., Los Angeles, Calif.
Mito, S. P., Takarazuka, Hyogoken, Japan
Moskowitz, C., Rutherford, N. J.
Myers, G. J., Westover, Mass.
Nakajima, M., Higashinoda, Osaka, Japan
Nelson, W. L., New York, N. Y.
Nemecek, J. F., Kansas City, Mo.
Olesen, A., Syracuse, N. Y.
Ornik, L. L., Vancouver, B. C., Canada
Oxild, P. E., Deer Park, L. I., N. Y.
Panosian, A. H., Boston, Mass.
Paulsen, R. C., Poughkeepsie, N. Y.
Petteway, A. B., Jr., Washington, D. C.
Pierpont, J. E., Jr., Poughkeepsie, N. Y.
Pierpont, R. W. W., Ypsilanti, Mich.
Pollins, P., Lexington, Mass.
Quacchia, G. M., Rio de Janeiro, Brazil
Quitter, W. M., Cincinnati, Ohio
Rawson, S. W., Los Angeles, Calif.
Reale, J., Jr., Windsor, Conn.
Reszka, A., Chicago, Ill.
Rosenberg, L. J., Winston-Salem, N. C.
Rousseve, C. J., Alhambra, Calif.
Saba, S. A., West Burlington, Iowa
Schneider, A. M., West Covina, Calif.
Sedillo, R. R., San Jose, Calif.
Shelton, W. L., Mountain View, Calif.
Sheppard, D. M., Jr., Poughkeepsie, N. Y.
Silberberg, M. Y., Pleasantville, N. Y.
Singer, E. N., Jamaica, L. I., N. Y.
Solomon, D. E., Baltimore, Md.
Spann, L. B., New York, N. Y.
Stafford, J. D., Panama City, Fla.
Stine, H. A., Seattle, Wash.
Teicher, S. W., Palo Alto, Calif.
Terry, R. W., Morristown, N. J.
Theodoropoulos, W. N., New York, N. Y.
Todd, E. P., Jr., Newburyport, Mass.
Tulledge, C. D., Kokomo, Ind.
Tweedie, T. C., Jr., Philadelphia, Pa.
VanderDoes, A. S., Lynchburg, Va.
Vincent, D. G., Wayne, Pa.
Wehmeyer, C. H., Oxnard, Calif.
Weiss, S., Philadelphia, Pa.
Wellhoner, J., Jr., Lynn Haven, Fla.
Wetzell, H. B., Brockton, Mass.
Wierman, E. T., Canoga Park, Calif.
Wilding, J. V., Clifton, N. J.
Wunsch, D. E., Endwell, N. Y.
Zentis, J. J., Rochester, N. Y.
Ziebell, D. H., Hatboro, Pa.
Zottarelli, L. J., La Canada, Calif.

Admission to Associate

Adams, J. C., Jr., Santa Clara, Calif.
Aedo, E. M., Vina Del Mar, Chile
Barnard, L. N., Alamogordo, N. Mex.
Beck, A. B., Hawthorne, Calif.
Bice, H. J., Channelview, Tex.
Contreras, P. F., Valparaiso, Chile
Coverick, J. M., Streator, Ill.
Cowan, R. A., Cleveland, Ohio
Cronk, T. G., Tucson, Ariz.
Davis, J. R., St. Louis, Mo.
Diaz, A. G., Bogota, Colombia
Dove, P., Jr., Flushing, L. I., N. Y.
Durham, K. M., Jr., Fort Worth, Tex.
Folsom, F. L., Jr., Hinesville, Ga.

(Continued on page 132A)

Professional Group On Microwave Theory and Techniques

The history of radio communications has been marked by continual, relentless progress toward the upper reaches of the frequency spectrum. By the early 1940's services which utilized frequencies as high as 150 mc were coming into quite general use, and considerable experimental work was going on in the uhf and microwave portions of the spectrum.

World War II and the advent of radar gave a tremendous boost to this upward climb through the frequency domain, so that today the microwave field has blossomed to a position of prominence—almost predominance—in the radio engineering art.

On March 7, 1952, this thriving field of activity received another important boost when the IRE formed a Professional Group on Microwave Theory and Techniques. For the first time, this important branch of the field was provided with its own organization for channeling and spreading vital, specialized knowledge to its own members and for stimulating a planned program of service tailored to the needs of the field. The value of the services being performed by the Group is attested to by the fact that more than 4500 engineers have joined and paid the modest $3 assessment fee.

The most important service provided by the Group is its TRANSACTIONS, which is issued quarterly to all Group members. In addition, special issues of TRANSACTIONS are published occasionally in order to give members the complete proceedings of important confrences which are held in the microwave and related fields.

The Group has also been very active in sponsoring conferences throughout the year. In addition, local meetings are held by Chapters of the Group in sixteen cities all over the country.

If the activities of the PGMTT are not history-making they are assuredly history-changing, for already these activities have altered the course and speed of progress in this field.

W. R. G. Baker

Chairman, Professional Groups Committee

Membership

(*Continued from page 130A*)

Foster, M. M., Anaheim Calif.
Gilliam, J. G., Ferndale, Mich.
Glover, J. M., Los Angeles, Calif.
Gutierrez, V. G., Santiago, Chile
Healy, M. J., West Los Angeles, Calif.
Heinrichs, R. M., St. Petersburg, Fla.
Honore, P. M., Santa Clara, Calif.
King, H. G., Rochester, N. Y.
Klein, M. J., Huntington Valley, Pa.
La Page, B. F., Cambridge, Mass.
La Puented, C., Lima, Peru
Larrick, R. W., Los Angeles, Calif.
Lehman, J. J., Philadelphia, Pa.
Malley, F., Alamogordo, N. Mex.
Massa, F., Jr., Hingham, Mass.
Matthews, W. C., Pomona, Calif.
McNicol, D. C., El Paso, Tex.
Miller, S. G., White Plains, N. Y.
Moeller, H. J., Groton, Conn.
Moreno, R. W., Daly City, Calif.
Mossman, J. M., Neosho, Mo.
Mukherjee, B., Calcutta, India
Neeman, C., Haifa, Israel
Ofner, F. R., Jr., Portland, Ore.
Penido, E., Rio de Janeiro, DF, Brazil
Perkins P. E., Dayton, Ohio
Pile, J. H., Maple, Ont., Canada
Pinto, E. A., Philadelphia, Pa.
Pinto da Luz, A.F.H.B., Rio de Janeiro, Brazil
Puga Martinez, A. E., Vina del Mar, Chile
Robb, B. V. R., Beverly, Mass.
Sadhu, J. N., Madras, India
Scheer, A. W., Jr., Huttig Ark.
Schmid, J. G., Ypsilanti, Mich.
Sheriff, K. A., Luqa. Malta
Shombert, D. J., Rahway, N. J.
Szymczak, R. S., Woburn, Mass.
Taraldson, J. H., Las Vegas, Nev.
Trent, J. H., China Lake, Calif.
Tsao, T. K., Beltsville, Md.
Weaver, C. E., Greenville. R. I.
West, A. A., De Witt, N. Y.
Winters, L. I., Hawthorne, Calif.
Wojciechowski V., Buenos Aires, Argentina
Wymond, W. H., Concord, Calif.

Section Meetings

ALAMOGORDO-HOLLOMAN

"Project Cateye. TV Tracking of Stars," J. Barton, Johns Hopkins Univ.; 4/20/59.

Demonstration and Tour—Geo-Science Inc.; M. W. Jones: 6/23/59.

BALTIMORE

"Visit to Russia," R. Harmon, Westinghouse Broadcast; Ladies Night Dinner; 5/16/59.

"Automatic Impedance Plotter," A. Alford. Consulting Engineering; Election of Section Officers; 6/10/59.

CONNECTICUT

"Magnetics, Key to Modern Control," E. Weir, Magnetics, Inc.; Jt. with PGNS; 4/16/59.

Tour—U.S. Army Nike Site Facilities; Election of Officers: 5/16/59.

EGYPT

"Design of Television Receivers," R. Nourki, Warsaw T. Plant; 8/5/59.

EL PASO

Election of Officers; 6/4/59.

Installation of Officers; 7/23/59.

(*Continued on page 146A*)

Positions Wanted

By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The IRE publishes free of charge notices of positions wanted by IRE members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

PROFESSIONAL ENGINEER

Broad experience in management and in engineering, seeks interesting remunerative and challenging association. Reg. Washington prof. eng.; BS. FCC licenses, etc. 14 years in broadcast, communications, FCC and management engineering. Senior Member, active on IRE technical committees; NTSC., etc. author 6 books, over 100 articles. Present contract expires shortly, do not wish to stay overseas. Prefer a south west state, Washington, D.C. fine; well known in industries. Excellent references. Box 2023 W.

ELECTRONIC ENGINEER

BSEE. 1955, MSEE. 1957; Eta Kappa Nu, Tau Beta Pi, Phi Kappa Pi. 3 years experience on radar simulators, UHF aircraft radio and circuit development. At present Army Officer (Signal Corps), available August 1959. Prefer Phila. area but will relocate for outstanding opportunity. Box 2024 W.

PHYSICIST

34 years experience in communication laboratory, desires position in southwest U.S. B.A., M.A., Ph.D. Member American Physical Society. Member IRE. Has worked in loudness studies, sound recording, network and filter design. Interested in statistical problems. Security clearance. Married. Box 2025 W.

MANAGER-ENGINEER

6 years diversified experience as corporate manager and engineering director with additional experience encompassing corporate organization, sales, advertising, publicity, public speaking and technical writing. 17 years electronics background in communications, instrumentation, radio and TV development and design. Registered professional engineer. BSEE. Purdue University; Senior Member IRE; Age 37; married; 3 children. Box 2026 W.

EDUCATOR-EDITOR-ENGINEER

BA., BSEE., MA.; MS.; Major USAF Res. 15 years experience training, writing and supervising engineering projects. Knowledge Spanish, Portuguese, Italian, French, German, Russian. International relations and Military Intelligence. Desires responsible position overseas. Box 2027 W.

(Continued on page 136A)

Positions Wanted

By Armed Forces Veterans

(Continued from page 135A)

DIGITAL SYSTEMS ENGINEER

BEE.; Tau Beta Pi, Eta Kappa Nu; graduate work in digital techniques. 6 years broad experience, logical design, systems integration. transistorized circuit design, systems evaluation. Married, 2 children. Desires position in Japan or other opportunity of unusual interest. Box 2031 W.

ELECTRICAL ENGINEER

Age 23. BEE. Georgia Tech. September 1957. 1/Lt. U.S. Army Ordnance Corps. 1½ years as project coordinator at White Sands. Desires position in missile instrumentation or allied field with management opportunities. Location southeast or southwest. Available November 1959. Box 2032 W.

ELECTRONIC TECHNICIAN

Signals Officer 15½ years service in HF communication work. Age 37. Associate Brit. IRE. Associate Member IRE (USA). Graduate H.R.T. Institute, Los Angeles. Desires suitable position, willing to undergo preparatory training if necessary. Non-U.S. citizen, at present residing outside USA. Location any part of the world, preferably US or possessions. Box 2033 W.

EDITOR-PUBLICATIONS MANAGER

BS. in physics; 10 years technical writing experience including 4 years as supervisor; 3 years teaching radio and television repair, laboratory and theory; holder of 1st class radiotelephone license; excellent mathematician; expert typist and stenographer. Desires position as editor of electronics periodical or as supervisor in publications section of manufacturer of electronic equipment. New York City area preferred. Box 2034 W.

TECHNICAL REPRESENTATIVE

Assistant to Technical Director in Europe desires position of broad responsibility in Europe. University training in eng. and administration; 10 years comm. and mil. elec. Member IRE; FCC 1st. Age 40. Married. Box 2035 W.

ENGINEER

Graduate mechanical engineer with electronic experience. LLB. August 1959. Age 28. Seeks position to encompass both fields. Desires small to medium company. Married. Location immaterial but favors overseas. Box 2036 W.

ELECTRONIC ENGINEER

Completing Ph.D. in E.E. this fall at large midwestern university. 6 years broad experience in ECM, communication, and control systems. Strong background in applied mathematics. Former Fulbright scholar. Desires long term position in continental Europe. Age 29, married, U.S. citizen, languages. Box 2039 W.

ELECTRONIC ENGINEER

BSEE. 1956 from Louisiana Tech; Professional Engineer, La.; FCC license; 3 years in radio equipment research and development. Desires diversified work involving planning and circuit work. Age 25; married; USAF officer; January 1960. Box 2044 W.

(Continued on page 138A)

THE FAR REACHES OF MAN'S KNOWLEDGE

Over the years ITT Laboratories has made significant contribution to advancing the state of the art in electronics. Today highly evolutionary progress is moving apace in such areas as broadband communications systems, low-noise parametric amplifiers, atomic clocks, inertial navigation systems, high density storage tubes, and space guidance, navigation and flight control. Major achievements are resulting in stored program digital computers and digital communications.

While engineers and scientists at ITT Labs meet the urgencies of today, they are simultaneously exploring the far reaches of man's knowledge, accepting small failures, making small successes, to unlock the doors to revolutionary achievements in electronics.

Communications, as essential to civilization as food and shelter, is an area of unlimited challenge which constantly occupies our efforts. To find more room within the radio spectrum for electronic communications — from direct current to the cosmic rays — is a major goal. Revolutionary ways to extend communications is another. We foresee early success with single satellite systems of the delayed-transponder type, and possibly passive reflector satellites. In only a few years ITT's "Earth Net" communication system may be a reality, providing global communications via three satellites in orbit. Within a generation, world-wide television may be a commonplace.

Positions of responsibility, challenge and reward are open to engineers with minimum B.S. degree and U.S. Citizenship. For information regarding specific positions, write G. T. Wall, Technical Placement Director.

ITT LABORATORIES

A Division of International Telephone and Telegraph Corporation

500 Washington Avenue, Nutley, New Jersey

Fort Wayne, Indiana • San Fernando and Palo Alto, California

Positions Wanted

By Armed Forces Veterans

(Continued from page 136A)

INSTRUMENTATION

Group Leader: instrument development for product improvement; development of unique applications of sound, light and electronics to measurement of various process parameters; and development of automatic equipment. 13 years experience; BS. Eng. Physics, MS. Electrical Engineering. Box 2045 W.

Positions Open

The following positions of interest to IRE members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. ....

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

Proceedings of the IRE
1 East 79th St., New York 21, N.Y.

ELECTRONIC ENGINEER

Electronic Engineer to teach lecture and laboratory courses. Up-to-date knowledge of the field required. Working and living conditions excellent; salary and opportunity very attractive. Write to dean of Engineering, California State Polytechnic College, San Luis Obispo, California.

SALES MANAGER

Sales Manager to direct all marketing activities of small manufacturer of VHF television distribution equipment, low noise and specialized amplifiers. Must have engineering education and substantial sales management experience. Considerable travel. Located in small academic community in mountains of central Pennsylvania for delightful living and family raising. Growth opportunity. Salary and stock option. Apply to Community Engineering Corp., Box 824, State College, Pa.

GEOPHYSICAL INSTRUMENT MAN

Position available for high-level electronic technician or BSEE. to work on instrumentation for mining geophysical prospecting and to develop research apparatus pertaining to same. Must have at least 5 years experience preferably in audio and sub audio frequencies. Must be capable of independent work. Laboratory in country near Danbury, Conn. Salary commensurate with ability. Write: Newmont Exploration Ltd., RFD 1, Danbury, Conn. Att: W. M. Dolan.

ELECTRONIC ENGINEERS

Career electronic positions for graduate engineers open with Federal Aviation Agency in Alaska. Employee, dependents, household goods moved at Government expense. Paid vacation travel each 2 years. Requires minimum 2 years technical electronic engineering experience. Salary $6285 and up plus 25% living allowances. Travel per diem $13 to $21. Airmail Federal application or qualifications resume to Box 440, Anchorage, Alaska.

(Continued on page 140A)

Positions Open

(Continued from page 138A)

DIRECTOR OF ELECTRONICS

Director of electronics R and D with aeronautical applications. Suburban location near New York City. Salary $30,000. plus. Doctor's degree desirable. Box 1098.

ELECTRONIC ENGINEER

Electronic Engineer, experienced in circuit design to do medical instrumentation. Will carry projects from design to finished products. Non-military, diverse work. Company in Philadelphia area. Opportunity to rise with small, growing company. Box 1099.

GRADUATE RESEARCH

Position open September 1, 1959, for prospective Ph.D. candidate with MA. degree in Electrical Engineering to develop electronic equipment and do research at a midwest university. Salary range to $600 per month for qualified individual. This position provides excellent opportunity to work towards a Ph.D. degree. Send qualification record and copy of transcript to Box 2000.

ASSISTANT OR ASSOCIATE PROFESSOR

Assistant or Associate Professor for Electrical Engineering Dept. MS. or Ph.D. degree required. Opening in electronics. Salary commensurate with experience and education. Write Head, Electrical Engineering Dept., South Dakota School of Mines and Technology, Rapid City, South Dakota.

TECHNICAL PERSONNEL

Young engineer or scientist with strong interest in people and education to work on college relations program. Duties: visit university Engineering and Science Depts. to interview applicants; advise faculty of Litton's technical programs; help develop graduate studies program. Apply: Mr. Joseph Ctyden, Litton Industries, Beverly Hills, California.

ELECTRONIC ENGINEERS

The U.S. Department of State has career openings for Electrical Engineers in Washington with possible future assignment overseas. For further details, write or contact The Office of Security, Department of State, 515 22nd St. N.W., Washington 25, D. C.

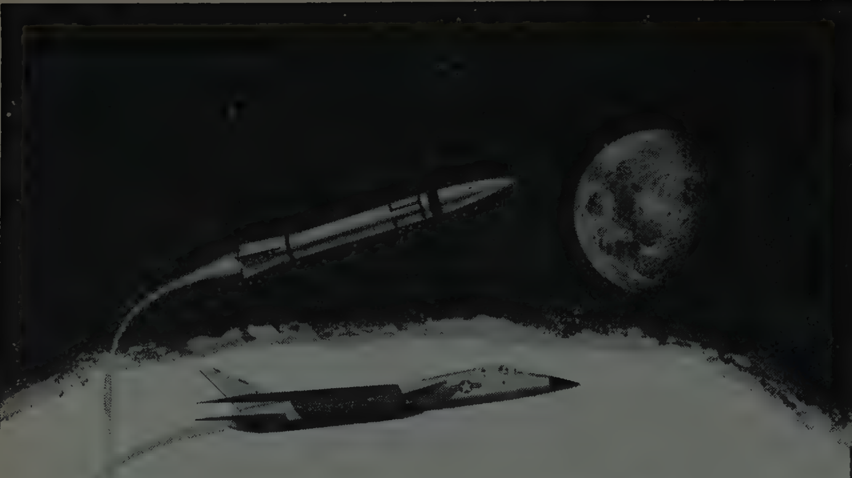
ELECTRICAL ENGINEERS

BS. and MS. Electrical Engineers for research work on instrumentation and control problems related to steel industry. Salary commensurate with training and experience. Large research laboratory. Pittsburgh area. Forward complete resume and salary requirements to Box 2002.

ENGINEER

Unusual opportunity for creative engineer to perform challenging, diversified work with Long Island quality instrument mfr. leader in millimicrosecond techniques. Excellent salary and room for rapid growth in active, congenial and expanding company. Requirements: 5 years development experience in pulse, transistor and high frequency circuits. Must be capable of assuming product responsibility. Apply Lumatron Electronics, Inc., 68 Urban Ave., Westbury, N. Y. Tel. EDgewood 4-3100.

(Continued on page 142A)



ADVANCED DESIGN

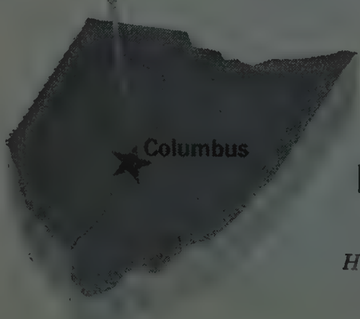
Several positions are available in the Advanced Design Section for senior engineers and scientists. Our Advanced Design Section is divided into two groups: Preliminary Design and Military Operations Analysis.

Preliminary Design engineers are responsible for both aircraft and missile configuration, performance, structures, propulsion, electronics, and support equipment. Intensive experience in any of these areas is a prerequisite.

The Military Operations Analysis group is investigating requirements for advanced Logistic, Defense, Attack and Reconnaissance Systems. This group is responsible for being familiar with the state of the art in all military weapons areas, using this information to optimize weapon proposals.

Current studies in Advanced Design are exploring new concepts in underseas warfare, land combat, and aerial warfare, including VTOL-STOL, missiles of all types, ground handling and support equipment, and other still confidential studies.

Engineers, Mathematicians and Physicists are invited to write for more information to Engineering Personnel, Box PI-498, North American Aviation, Inc., Columbus, Ohio.



THE COLUMBUS DIVISION OF NORTH AMERICAN AVIATION, INC.

Home of the T2J Buckeye and the A3J Vigilante

Positions Open

(Continued from page 140A)

ENGINEERS OR PHYSICISTS

Senior and Junior career positions are open on our research and development staff for engineers or physicists with experience in electronic circuit design. Projects are challenging and broad in scope, conducted in an academic atmosphere at industrial levels of compensation. Send resume in confidence to Dept. 14, Paul Rosenberg Associates, 100 Stevens Ave., Mt. Vernon, New York.

PROFESSOR AND ASSOCIATE PROFESSOR

Professor and Associate Professor of Electrical Engineering—To teach graduate and undergraduate subjects and to participate in developing research program in a southern university. Good location in an industrial region. Competitive salaries for various levels of education and experience. Box 2003.

TEACHING-RESEARCH

The new Electrical Engineering Dept. at the University of Rochester is seeking to expand its staff, and has openings on its faculty for qualified Electrical Engineers and Scientists interested in positions combining teaching and research responsibilities. Salary scales are fully competitive with other leading institutions, and are designed to interest people of the highest competence. Write, including resume, to Daniel W. Healy, Jr., Head, Dept. of Electrical Engineering, University of Rochester, Rochester 20, New York.

ELECTRONICS ENGINEER

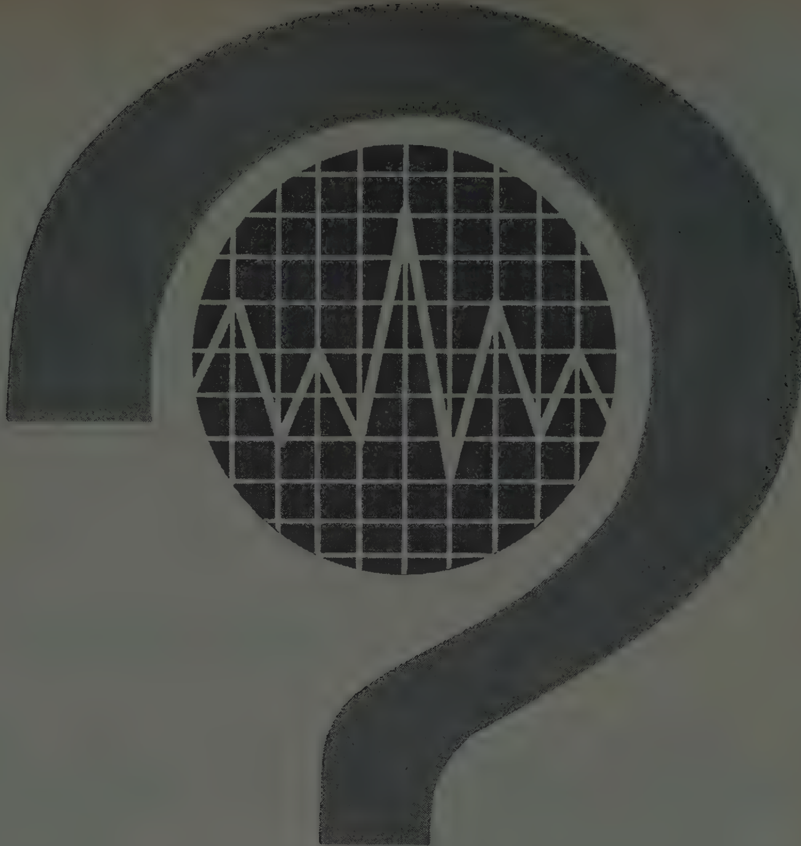
Our company is setting up a new industrial electronic group and may have just the position you are seeking. We would like to engage a man capable in the application of electronic measuring and control systems to industrial processes. Prefer he be familiar with electrical laboratory test equipment and current in knowledge of available instrumentation. Knowledge of pulse techniques and transistor circuitry background would be very helpful. Reply immediately giving education, experience, age and salary expected. Box 2004.

TEACHING-ELECTRICAL ENGINEERING

Additions to electrical engineering faculty desired by engineering school of midwestern university at all professorial ranks. To conduct research and teach both graduate and undergraduate classes. Research interests of considerable importance. Send resume of education and experience to Box 2005.

CHIEF MICROWAVE ENGINEER

If you can assume the electrical design and test functions responsibility for an outstanding company devoted exclusively to the manufacture of microwave components, (such as mixer-duplexers and antenna assemblies), this is the opportunity you have been searching for. Your ability will be the only factor in establishing the scope of your authority; your income will be commensurate. We offer liberal benefits, a substantial future and professional freedom and growth. Send complete resume in confidence to Personnel Dept., Budd-Stanley Co. Inc., 43-01 22nd St., Long Island City 1, N. Y.



WHAT ATTRACTS TOP ENGINEERS TO STROMBERG-CARLSON

In the opinion of our technical people, Stromberg-Carlson's philosophy of fine engineering has had a lot to do with the record growth of its engineering and scientific manpower in the last 5 years—an increase of 583%.

And corollary to this, the company's established reputation for quality engineering, design, production ("there is nothing finer than a Stromberg-Carlson") is a decisive factor in the award of major contract responsibilities in such diversified and advanced areas as:

- **nuclear instrumentation for Enrico Fermi Atomic Power Plant**
- **new applications of solid state technology, including the Euclid Modular concept in data handling systems**
- **sonar detection systems and other ASW projects**
- **a large scale, electronic passive reconnaissance system (for which Stromberg-Carlson is both Prime Contractor and Systems Manager)**
- **a revolutionary development in telecommunications for military field service (its all-transistorized electronic switching system operates without moving parts)**

If you take pride in fine engineering, and have professional capacities in any of the areas listed, why not look into the opportunities here. Please address resumes, including salary requirements, to Robert L. Ford.

Positions are available for design and development engineers at intermediate to senior levels to work in fields involving navigation control systems, electronic countermeasures, anti-submarine warfare systems, communication systems and telecommunications. The following type of experience is required:

CIRCUIT ENGINEERING. Logic circuits, control circuits, switching, storage, detector, display.

TRANSMISSION ENGINEERING. Electro-magnetic propagation, antennas, wire propagation, wave guides.

COMMUNICATIONS ENGINEERING. Voice studies, data studies, coding and modulation, security and reliability.

TEST ENGINEERING. Factory electronic test, field service and automatic test equipment design.

TECHNICAL PUBLICATIONS. Instruction book, proposal, military and commercial handbook writers with electronic backgrounds.

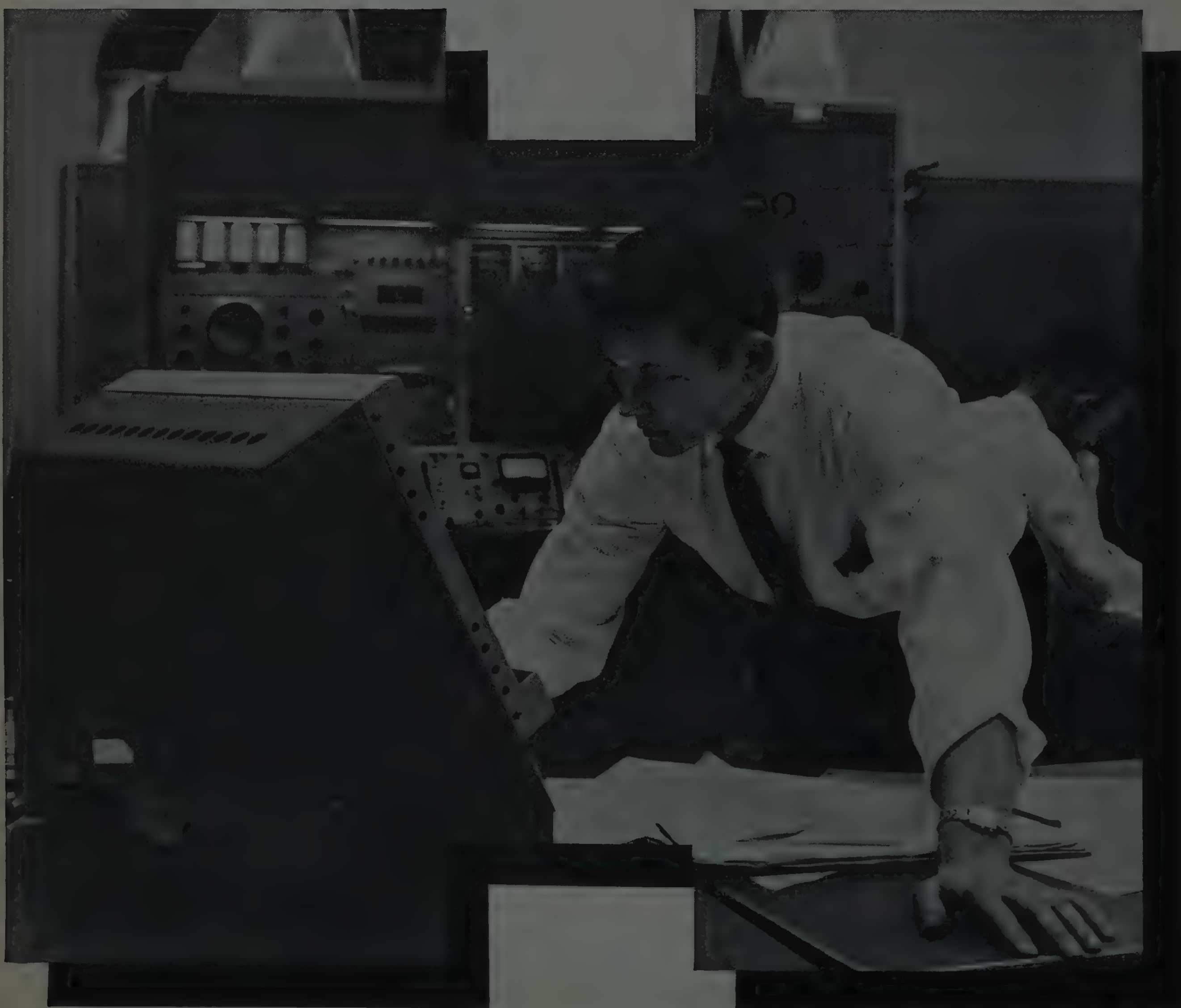
PHYSICISTS. Backgrounds in solid state, electron physics, and acoustics with heavy emphasis on mathematics.

STROMBERG-CARLSON

A DIVISION OF **GENERAL DYNAMICS**

1476 N. GOODMAN STREET, ROCHESTER 3, NEW YORK

creating controls



Section Meetings

(*Continued from page 132A*)

Florida West Coast

"First Step Into Space," R. Early, WFLA-TV; Annual Banquet Meeting; 6/19/59.

Hamilton

"Electronics and the IRE in Canada," A. P. H. Barclay; 4/13/59.

Montreal

"The Transmission of Information in the Presence of an Interfering Signal," T. E. Hayes, Canadian Broadcasting Corp.; Annual Dinner Dance; 2/13/59.

"The Hall Effect and Its Applications," C. Champness, Northern Electric Co., Ltd., "A Capacitive Wave Profile Recorder," A. Lapin, McGill Univ., Student Award Presentation; 3/17/59.

"The TJ Radio System," Members of Communications Equipment Div., Northern Electric Co., Ltd.; 4/14/59.

"How Stereo Works," R. H. Tanner, R & D Labs, Northern Electric Co., Ltd.; "Practical Design Considerations in a Good Stereo System," F. H. Margolick, Electrical Products Co.; Election of Officers; 5/14/59.

"The Space Age and IRE," Dr. Ernst Weber, IRE President; "On Target" Film of Firing of an Atlas ICBM; 6/22/59.

Orlando Section

"1969 Astronautic Systems," M. Alperin, AFOSR; "Operation Farside," Film; 6/16/59.

San Diego

"Semi-Conductor Physics and Devices," B. M Williams, Texas Instruments; 7/7/59.

"Special Purpose Circuits for 'Special Services,' " E. Wiedmann, Bell System; 8/4/59.

Toledo

Tour, Triplett Plant; 4/11/59.

"Anomalies in Engineering and Research," N. Glyptis, Multi-Tron Labs. Inc.; Election of Officers; 6/11/59.

Williamsport

"Vibration and Vibrators," M. W. Tustin, Textron Electronics, Inc.; 6/25/59.

SUBSECTIONS

Buenaventura

"Air Central Data System," J. McEwen, AiResearch, Garrett Corp.; 6/10/59.

Reading

"The Engineering Profession From a Woman's Point of View," B. B. Small, Western Electric Co.; 6/17/59.

Richland

"The Size of the Universe," B. Brenden, GE Co.; Election of Officers; 6/11/59.

Santa Ana

"Meteorology in the Space Age," I. P. Krick, Irving P. Krick Associates Inc.; 6/24/59.

Coming Soon!
The 1960
IRE DIRECTORY

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 48A)

Power Amplifier

A three channel power amplifier, designed specifically for driving fluid damped high frequency galvanometers from low level signals has been announced by **Columbia Research Laboratories,** MacDade Blvd., and Bullins Lane, Woodlyn, Pa.

The new instrument, the model 8003, has been developed to improve the recording of shock and vibration data in systems involving crystal type accelerometers.

The model 8003 handles the full range of amplitudes and frequencies associated with piezoelectric transducers. Its flat response from 1 cps to 20 kc covers the entire accelerometer range. Low noise (20 microvolt rms) and high gain (0.3 to 1000) allow operation with all levels of sensitivity.

Input impedance is 1600 megohms for coupling to high impedance transducers and an unusually low output impedance of 1 ohm for driving low impedance galvanometers. Its output overload voltage is 10 volts peak to peak with current up to 200 milliamperes.

The front panel is equipped with coarse and fine adjustments for precision gain control. In addition, there is a special transducer calibration control which allows adjustments for accelerometers of different sensitivities.

Transistor and Rectifier Acid Etching Machine

This machine developed by **Carman Laboratories, Inc.,** P.O. Box 328, Bedford, Mass., is intended for performing the stream etching, quenching and first rinse operations on transistors and rectifiers. Of the twelve index positions nine may be used for the etch, quench, and rinse operations in nearly any type of program desired. In most cases additional rinsing is recommended, however, the machine's rinsing is quite effective.

The etching machine consists of a 12-station indexing wheel, an array of nine pairs of ball-socketed jet nozzles mounted in a tank with the manifolds and tubing

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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

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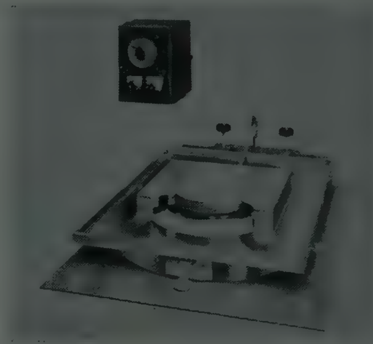
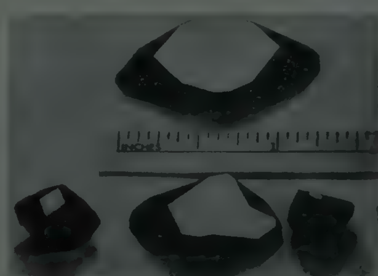


connections all below the water level. The index mechanism mounted on the underside of the tank is controlled by an adjustable timer so that the etching cycle can be varied at will.

The operating rate of this machine is dependent upon etching cycle and operator loading rate. For most transistors and rectifiers, the rate is between 1200 and 24000 per hour. If, for example, a 10 second etch is desired, five stations may be used for this purpose, resulting in a rate of 1800 per hour. This gives the operator two seconds to load and unload the parts. At the end of the acid etching sequence, it is often desirable to quench the etch in either hydrogen peroxide or fuming nitric acid. Usually one station is adequate for this purpose. The remaining stations can then be used for water rinses. Price $4800.

Large Iron-Garnet Crystals

Large single cytstals of Gadolinium-Iron-Garnet are now being commerically produced by **Microwave Chemicals Laboratory, Inc.**, 282 Seventh Ave., New York 1, N. Y. These single crystals are currently available in weights of 4 grams and over. They have a density of 6.49 gm/cc based on a lattice constant of 12.469 A° ± .005. Their saturation magnetization is approximately 50 gauss/cc at room temperature.



Like Yttrium-Iron-Garnets, these single Gadolinium-Iron-Garnet crystals are transparent in thin sections. They display their magnetic domain movement when a

(Continued on page 153A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(*Continued from page 150A*)

small permanent magnet is moved in their vicinity. The Curie temperature of these single crystals is 296°±1°C.

Potential applications are in the high frequency and microwave regions as well as in magneto-optical devices. The non-reciprocal properties of these crystals may be used over a broad frequency range. The crystals are machinable into lenses and an optical finish is obtainable.

Additional data on single crystals may be secured by writing to the manufacturer.

Sub-Miniature Rate Gyro

A New sub-miniature rate gyro produced by **Whittaker Gyro Div., Telecomputing Corp.,** 16217 Lindbergh St., Van Nuys, Calif., and embodying eddy current damping withstands temperature ambients from −65° to 400°F. The new gyro is a single degree of freedom instrument intended for missiles, drones, radar antennas, or anywhere that weight, size and performance under severe environment are critical. Overall diameter is $\frac{3}{4}$ inch.

The gimbal element weight and inertia are small, making flotation unnecessary and providing a favorable gimbal to rotor inertia ratio.

The rotor, mounted on high temperature spin bearings, is powered by a rapid starting hysteresis motor. An open type gimbal uses frictionless flexture pivots, which provide stable support throughout the most severe environment.

Angular deflection of the gimbal about the sensitive axis is measured by a variable reluctance pickoff which has a high signal-to-noise ratio and extremely fine resolution.

Output is governed by the rate range and the natural frequency. Rate ranges of 10 to 200°/second are available.

Power requirement for the three phase hysteresis motor and the single phase microsyn is 26 volts. Frequency range is 400 to 1000 cps depending upon performance requirements. The case is $\frac{3}{4}$ inch diameter by 2 inches and is hermetically sealed. The electrical connections are individual external solder lugs.

For further information on the sub-miniature rate gyro, contact the firm.

Inexpensive Transistor

Texas Instruments Incorporated, 6000 Lemmon Ave., Dallas 9, Texas, introduced a series of high performance all purpose

(*Continued on page 154A*)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued on page 153A)

economy germanium transistors including types to sell as low as 50 cents in quantity lots.

Prices for the entire general purpose series are 20 to 30% under those prevailing for competititive units.

The series includes ten types of transistors for general purpose industrial applications and six types for entertainment.

Perfection of a new header manufacturing process which directly seals the glass header to the metal case, permitting almost complete mechanization of production techniques, is credited by the firm with making the new transistors available commercially at low prices.

The ten commercial types were announced for such general purpose applications as medium frequency switching, servo amplification and use in many other circuits requiring high reliability and low costs.

TI-developed Continuous Automatic Testing (CAT) equipment, each machine capable of testing 1,800 transistors an hour and eliminating the chance for human error, is used to test and classify the new transistors.

Synthetic Sapphire

A series of new traveling wave tubes ranging in size from one that is slightly larger in diameter than a pencil lead to a giant almost a yard long has been developed and built at the Electronics Research Laboratory, Stanford University, using single crystal synthetic sapphire rod to support the helices.

The crystal material, a product of **Linde Co., Div. of Union Carbide Corp., Crystal Products Dept.,** 300 Madison Ave., New York 17, N. Y., was selected because it offers flexural strength at elevated temperatures, small-diameter rigidity,

(Continued on page 156A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 154A)

good dielectric properties, zero porosity, low-loss characteristics, and economy.

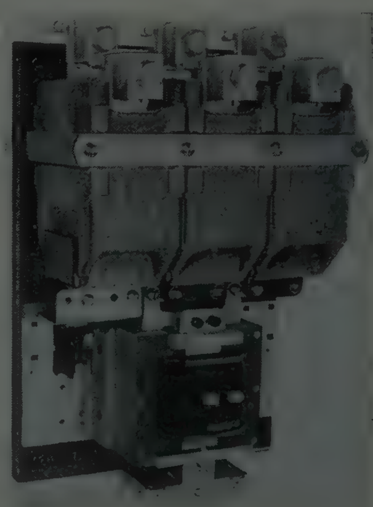
The three rods supporting the bifiliar helix and electron gun structure (above) at three points were grown in Verneuil furnaces and then centerless ground for proper dimension throughout.

In this photograph of a large backward wave oscillator built at Stanford, two of the sapphire rods are visible at the extreme right and left edges. The third, partly covered, can be seen just below the helix. The tube operates from 500 to 1000 mc at 100 watts.

Linde has been able to produce lengths up to 48 inches and in diameters from 0.010.

AC Switch

A new 300 ampere, standard NEMA Size 5, AC solenoid contactor has just been announced by **Ward Leonard Electric Co.**, 83 South St., Mount Vernon, N. Y., increasing their contactor line from Size 00 to 5 inclusive. Long life, simple solenoid design and compactness, are key features of the new Size 5 contactor.



Designed primarily for use in motor starters and controllers, they are also recommended for heater and lamp switching. Heavy inrush currents are handled by double contacts, enclosed in individual arc hoods.

Extra, fully accessible N.O., N.C., or low power auxiliary contacts are available, extending the contactors usefulness. Pressure type connectors are supplied for all control wiring, while clamp type terminals are standard on main poles.

Standard coil voltages are: 110, 208/220, 440 and 550 volts, 60 cps.

The basic contactor measures $10\frac{1}{2}$ wide, $17\frac{3}{8}$ inches high $\times$ 8 inches deep.

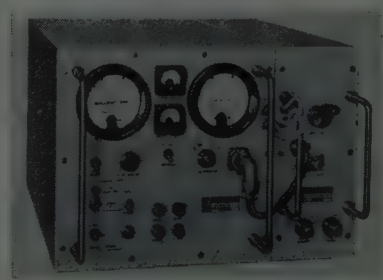
(Continued on page 158A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 156A)

Microwave Stability Tester

A new, multi-band, microwave stability tester is now being produced by **Pitometer Log Corp.**, 237 Lafayette St., New York 12, N. Y., manufacturers of radar components and test equipment. The PITLOG Series 800 Stalo Tester is designed for use in any application where a precise measurement of frequency stability is required.



Offering unusual accuracy and versatility, this equipment measures long term drift and short term deviation in frequency bands between 1100 mc to 10,000 mc, and its primary purpose is to check the stability of radar systems components such as stalos, cohos, klystrons and other stable signal sources, either on the production line or in the field. Other applications include troubleshooting of Moving Target Indicator radar systems; isolating sources of frequency disturbances; maser and parametric amplifier evaluation; radio astronomy.

PITLOG Series 800 Stalo Tester comprises two main sub-assemblies, one fixed and one interchangeable. An indicator unit, Model 800, houses the measuring circuitry and power supplies, and the two interchangeable units, Models 801 and 802, are used to heterodyne the signal down to the input range of the indicator. The interchangeable sub-assemblies contain the heads for a given frequency band. Model 801 covers L/S-Band—1100 to 3200 mc, and Model 802 covers X-Band—7000 to 10,000 mc. It should be noted here that the frequency range can be extended to include any frequency range from 75 to 10 kmc by the use of additional tuning units.

The apparatus affords direct reading of dynamic meter measurements of the long term and short term frequency stability of CW signals. Short term accuracy: 1 part in 10^9; long term accuracy: 1 part in 10^6. In addition, the short term stability distrubance waveform (FM) can be observed on an oscilloscope or spectrum analyzer. These stability measurements can be used to determine cancellation ratio and subclutter visibility limitations imposed by the stable frequency components on Moving Target Indicator radar systems.

(Continued on page 161A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 158A)

Clare Announces New 11-Point Stepping Switch

A new 11-point spring driven stepping switch, the Type 211, is announced by **C. P. Clare & Co.,** 3101 Pratt Blvd., Chicago 45, Ill., manufacturers of relays and electronic components. Laboratory and field tests indicate that this new switch gives longer service life, requires less maintenance, and provides greater capacity than previous 11-point switches. The improved performance results in part from elimination of pawl bearings, along

with the addition of heavier duty armature bearings, arms, and other new features. The new switch will accommodate twelve 11-point levels and up to four 33-point levels. It will operate for approximately 100,000,000 steps between adjustments. Orders are now being accepted for samples with production qualities available in the late fall. Complete information contained in Engineering Bulletin CPC-3.

Ultrasonic Cleaners

A miniature bench-size vapor degreaser, a one-kilowatt 35-gallon capacity ultrasonic cleaning system, a dual-purpose laboratory size cleaning and processing unit and a number of other ultrasonic cleaning machines were introduced to the industry by **The Narda Ultrasonics Corp.,** Westbury, N. Y., at Wescon.

The D-601, a one-gallon capacity vapor degreaser, is believed by Narda to be the smallest machine of its kind. The D-601 is designed to insure that after a part has been cleaned ultrasonically, it is absolutely free of any residual contaminated solvent when it is removed from the bath. This is

(Continued on page 162A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 161A)

accomplished by suspending the part in the condensing vapors of pure distilled solvent.

The dual-purpose cleaning and processing unit is the SonBlaster Series 400 consistenting of a Model G-401 ultrasonic generator and a Model NT-401 transducerized tank. Items can be cleaned or processed simultaneously in two 400 ml. Pyrex glass beakers, each with different solutions, or in the tank itself as a single unit. The series 400 is a compact table model which costs $275, and operates from a 115-volt, 50/60 cps outlet.

In the 1 kw range of king-size ultrasonic cleaners, Narda introduced its SonBlaster Model G-10001 ultrasonic generator (illustrated) and Model NT-10001 35-gallon capacity tank. Barium titanate transducer elements are integrally mounted to the bottom underside of the tank in such a way as to make the tank bottom a diaphragm which generates uniform ultrasonic vibrations throughout the entire contents of the tank measurig $18 \times 24 \times 18$ inches deep. Priced at $2555 complete.

Another in the line of ultrasonic cleaners is the automatic pushbutton-operated, two-stage ultrasonic vapor degreaser the "Jupiter" Model DVC-3000. This unit, which is priced at $2,990, has a boiling sump, a 300-watt ultrasonic cleaning chamber, distillate reservoir, power spray rinse and filter recirculation system featuring all stainless steel plumbing. Solenoid valves operated by push buttons on the front control panel regulate all draining, filtering and recirculating functions of the machine. It has a six-gallon capacity ultasonic immersion sump measuring $16 \times 8 \times 8$ inches deep. The overall dimensions of the cabinet are 56 long, 32 high and 23 inches wide.

Electronic Millivoltmeter

A chopper-stabilized electronic millivoltmeter, announced by **Metronix, Inc.**, Chesterland, Ohio, measures dc voltages from 0.0005 to 300 volts.

Operating on power frequency of either 60 to 400 cps, Model 301 has 10 standard voltage ranges, from 0.01 to 300 volts

(Continued on page 164A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 162A)

full scale. Its meter, with an arc length of $5\frac{1}{8}$ inches, provides easy readout.

Two feedback loops achieve good operational stability of this instrument and make it largely independent of voltage variations. An ac loop is in the circuit of the ac square wave amplifier. A dc loop, including the chopper itself, is established by returning the metered demodulated signal via the chopper to the input of the instrument. These features insure stability and accuracy regardless of tube aging.

The zero-center Model 301-C is suitable as a voltage-sensitive null indicator.

While Model 301 was primarily designed for low-voltage measurements in panel mounting applications, it is also available in a portable version.

For applications where control as well as indication is required, the instrument is available with a meter-relay instead of the conventional meter. Models 301-CMR and 301-C-CMR are both equipped with double locking contacts mounted on adjustable pointers.

Test Stand for Transformers

A new test stand, Model PMB-100-C, has been designed by **Schaevitz Engineering**, Pennsauken, N. J., for precise measurements of LVDT (linear voltage differential transformer) response to linear core motion independently of installation.

The LVDT case is clamped in the mount, and a non-magnetic, non-conductive core rod is used to position and support the core as the micrometer is adjusted.

Base and micrometer mounting block are constructed of silver-anodized aluminum. Mounting block and terminal strip are phenolic. There are five push-type binding posts mounted on the terminal strip for interconnecting the LVDT and the test circuitry.

(Continued on page 166A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 164A)

The LVDT test stand is normally used with a signal generator, amplifier, precision potentiometer, voltmeter and an oscilloscope, to measure and test linearity, phase, input and output volts and operations at various frequencies.

Wheatstone Bridge

Leads & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa., is now offering an improved 4232-B High Precision Guarded Wheatstone Bridge.

The old bridge's plugs and blocks have been replaced with enclosed rheostat dials and selector switches. The result is faster and easier operation by merely turning the dials and taking a direct reading from the windows above each dial.

Unlike its predecessor, the new bridge provides complete guarding which eliminates errors caused by adverse humidity conditions and resulting leakage currents. This guarding assures accuracies of ±0.01% up to 1 megohm and ±0.02% up to 100 megohms. The bridge has wide measurement range—from 0 to 11, 111 megohms—or 100 times greater than the former bridge's range.

Resistors may be tested with the new instrument at full battery potentials up to 100 volts, in accordance with the maximum values permitted in military specifications. Guard terminals are also provided so that the bridge guard system can be completed with a guarded dc bridge power supply and a guarded detector. With each instrument L & N supplies a certificate based on its own high standards which are certified at intervals by the National Bureau of Standards.

Housed in a gray metal case, the bridge is designed for mounting in a 19-inch relay rack, while an optional set or brackets permits table-top mounting. For further information, write for Preliminary Data Sheet #-53 (1B).

Gearmotor

The Electro Products Div., Western Gear Corp., 132 West Colorado Blvd., Pasadena, Calif., announces the design and manufacutre of a one hp gearmotor less than 2½ inches in diameter. This miniaturized gearmotor, identified as Model 70DC1RTO, requires 28 volt dc at 65

(Continued on page 168A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

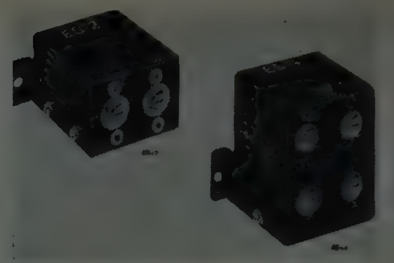
(Continued from page 166A)

amperes. Output speed can be varied in accordance with customer requirements. The model illustrated has an output shaft speed of 7,000 rpm.

For further details on this miniaturized gearmotor, write to firm. A copy of a complete rotary electrical equipment catalog can be obtained by mentioning Bulletin 5721.

Amplifier and Amplifier Power Splitters

An all-band, long-life amplifier and two series of amplifier power splitters, both designed for use in all applications of the new Entron Master Television Antenna System, were recently announced by Entron, Inc., P. O. Box 287, Bladensburg, Md.



The SA-23 Amplifier, a high gain, high output amplifier, provides a band pass of 54 to 88 mc and 175 to 216 mc with a 38 db gain on each band. Separate tilt and gain controls are provided for each band with a 13 db gain control range. The SA-23 has a multi-channel output of 53 dbmv, silicon rectifiers, and 10,000-hour-type 6922 input tubes insure maximum operation efficiency. The SA-23 is equipped with Entron TUG-PLUG* quick-disconnect fittings for ease of installation.

TUG-PLUG design also insures quick connection of the unique chassis of the amplifier power splitters, Models ES-2 and ES-4, to amplifier power output, and insures low insertion loss. High line-to-line isolation is provided by the ES-2 and the ES-4 which have a bandwidth of 50 to 225 mc with an impedance of 175 ohms.

Both the amplifier and the amplifier power splitters are small, and the amplifier weighs 6½ pounds and measures 12×

(Continued on page 170A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

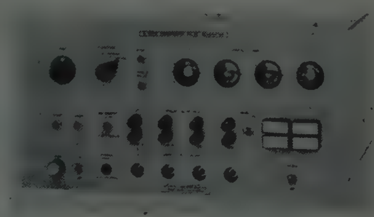
(Continued from page 168A)

$4\frac{1}{2}\times5$ inches, the ES-2 measures $2\frac{1}{8}\times 2\frac{1}{4}\times1\frac{1}{4}$ inches, and the ES-4 measures $2\frac{1}{8}\times2\frac{1}{2}\times2\frac{1}{4}$ inches.

Further information concerning the equipment and the complete Master Television Antenna System is available from the firm.

* Reg. T.M.

Pulse Generator



Testing of specific digital subsystems is simplified with the use of a new series of custom and standard Programmed Pulse Generators developed by **Iconix, Inc.**, 945 Industrial Ave., Palo Alto, Calif. A typical model, the II-507B, delivers four different pulse programs to two signal outputs with sync pulses at various PRF's. A continuous pulse train provides a fourth output. A preset counter is incorporated allowing choice of a number of pulses or words per program, which may consists of 10 bit words or a continuous pulse train. Exclusive use of transistors and cold cathode gas tubes reduces power consumption to eight watts and considerably enhances the instrument's reliability. Modular construction makes available many variations from the standard generator as well as permitting a low price for equipment of this type. For prices and other information contact the firm.

Germanium Crystal Ribbon

It has been disclosed by **Westinghouse Electric Corp.**, Box 2278, Pittsburgh 30, Pa., that scientists have constructed long ribbons of semiconductor devices by forming them along the surface of long, thin crystals of germanium about an eighth inch wide and a few thousandths of an inch thick. Such construction appears to be feasible for the automatic production of transistors and other solid state devices directly by machine.

These devices demonstrate the ultimate usefulness of a new method for growing germanium which was recently discovered. This technique grows the germanium as thin, flat continuous strips, or dendrites—the exact form in which it can be used directly in finished semiconductor devices.

The development of working devices from dendrites is being carried out under a "molecular electronics" contract recently awarded to Westinghouse by the

(Continued on pages 174A)

professional opportunities

We offer an academic environment in mid-Manhattan of superior technical standards and high professional calibre. The work involves development of systems concepts (particularly weapons systems) under prime Government contracts. Opportunities for rapid and orderly growth are exceptional.

Our associates already have distinguished records in these fields:

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Members of Republic's Scientific Research Staff have been carrying on independent investigation in a progressive research environment since the formation of the group three years ago. Each individual is encouraged to pursue areas of research in which he feels he may make the greatest contributions.

The ability of this environment to aid in bringing theoretical concepts into the realm of feasible engineering has been amply demonstrated. An example is the Plasma Pinch Engine conceived by members of this staff. Originally backed by Republic funds, it is now receiving supplemental support under government contracts. Among other research in advanced stages are programs on lifting fans and new methods of structural analysis.

TODAY THE RESEARCH STAFF IS BEING AUGMENTED— to emphasize existing areas and to open new ones.

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Write in confidence directly to Dr. Theodore Theodorsen,
Director of Scientific Research

REPUBLIC AVIATION

Farmingdale, Long Island, New York

NEWS New Products

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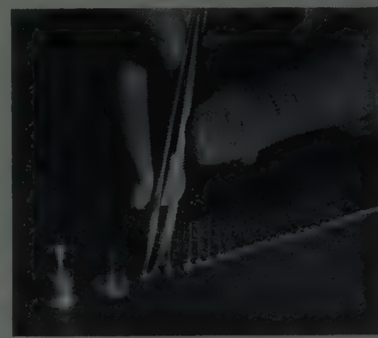
(Continued from page 170A)



Air Force's Air Research and Development Command.

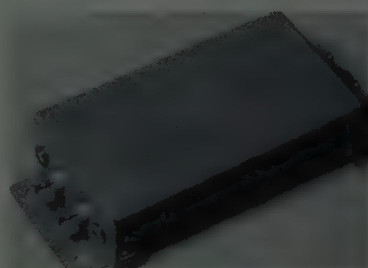
In molecular electronics one seeks to combine several separate electronic functions into a single operating unit that duplicates their over-all electrical behavior. For example, a single tiny slab of solid material that performs the function of a combination of transistors, resistors, capacitors, plus other circuit components, and yet contains none of these components, as actual entities.

To perform such an operation, a solid state device must reach an entirely new order of perfection. Conventional ingots of semi-conductor materials, which must go through tedious and complicated manufacturing procedures, are not likely to yield the near-perfect devices required for the job.

Crystalline dendrites can make such units possible. Their quality is more uniform because of the unique way in which they grow; furthermore, their desirable properties are not jeopardized by long and complex processesing into usable form.

These characteristics, and the fact that they grow as high-quality continuous ribbons, make dendrites also appear to be the only form of material that now looks feasible for the fully automatic production of semiconductor devices.

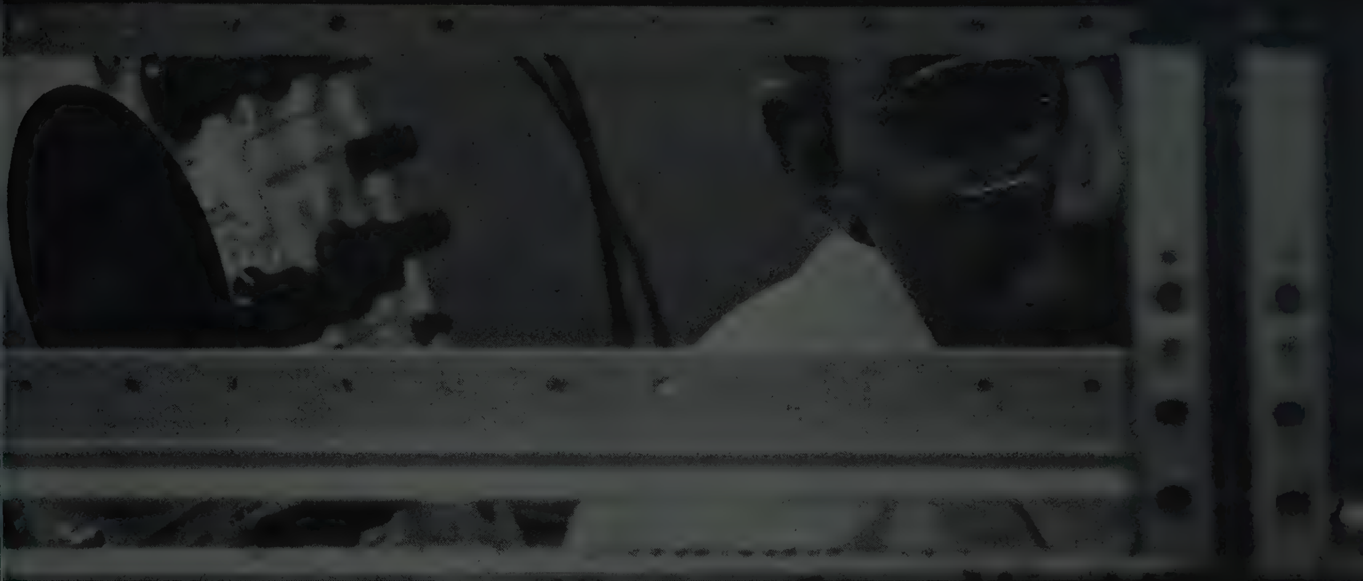
Power Supply



Bomac Laboratories, Inc., 1 Salem Road, Beverly, Mass., has recently announced a new keep-alive supply—the BL-N-004. It is capable of supplying 170

(Continued on page 178A)

If your career interests are in electronics and missile sciences



and you possess creative foresight

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RADAR SYSTEMS

OPERATIONS ANALYSIS

INERTIAL REFERENCE SYSTEMS

FEED-BACK CONTROL

AUTO-PILOT

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ELECTRONIC PACKAGING

TEST EQUIPMENT DESIGN

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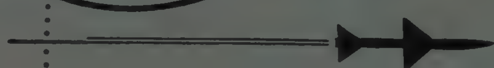
(Background in missile control and auto-pilot design)

MECHANICAL ENGINEERING
(Background in ground handling of large missile systems)

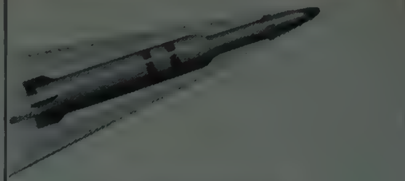
MICROWAVE TUBE DESIGN

Please send resume to Mr. W. F. O'Melia, Employment Manager, Raytheon Company, Bedford, Massachusetts, or call collect: CRestview 4-7100, Extension 2138.

RAYTHEON *MISSILE SYSTEMS DIVISION*



ELECTRONICS: Over, on and under...



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Manager, Employment Services
Dept. C-106
9150 East Imperial Highway
Downey, California

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A Division of North American Aviation, Inc.

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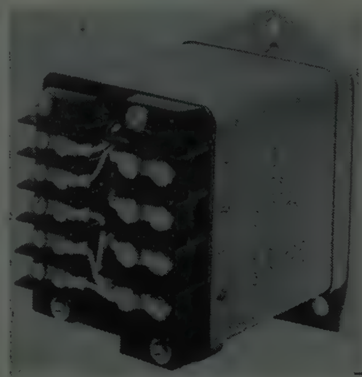
(Continued from page 174A)

microamperes at 750 vdc from a 28 vdc source. The output voltage variation is held to $\pm 3\%$ when the input voltage is varied between 22 and 34 volts. The output current is limited by a self-contained 4.7 megohm resistor. Both the input and the output terminals are isolated from the case. Physical dimensions are 5 L $\times$ 2 W $\times 1\frac{1}{8}$ inches H.

Overtemperature Relay

A direct monitoring overtemperature relay device for use in a wide range of ac applications has been developed by **Cutler-Hammer, Inc.**, 372 N. 12th St., Milwaukee 1, Wis.



The new product consists of a magnetic relay, two transistor amplifiers, a diode network for signal separation and a voltage regulated power supply.

Though specifically designed to protect 3-phase ac motors, this relay is suitable for use wherever overtemperature is a problem.

Chief advantage of the new design is that it permits maximum use of equipment without danger of overheating because the component responds only to the actual temperature of the protected equipment. This, of course is due to the fact that the thermistor is inserted in the windings of the motor, generator or transformer.

Power supply ratings are 110, 208/220, 440 or 550 volts, 60 cps. Contacts are the pilot duty type, 600 volts ac maximum

For further details, write to the firm.

Pull-Push Switches

Chicago Telephone Supply Corp., Elkhart, Ind., offers 2 new 13/16 inch diameter pull-push switches in separately mounted styles for electronic and electrical applications requiring greater simplicity of motion and easier handling than possible with rotary and toggle switches. A light pull turns on the switch, a light push turns it off. Type SK-1 has 8/17 ounce actuating

(Continued on page 183A)

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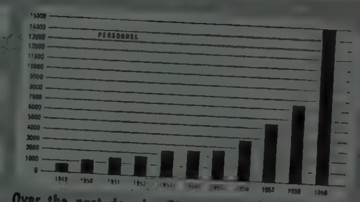
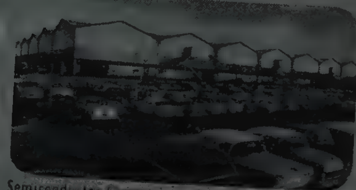
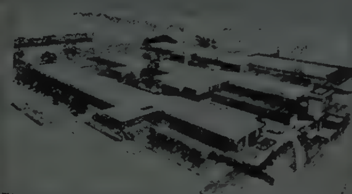


Over the past decade, TI personnel increased over 15-fold from 800 to almost 14,000. Will be 15,000 by end of 1959.



Semiconductor-Components plant . . . world's largest semiconductor manufacturing facility. Construction underway will more than double its size.

Typical of all TI plants and offices, the Apparatus division assembly area is well-lighted and air-conditioned.



TI Central Research Laboratory's new building, located adjacent to the Semiconductor-Components plant at the 300-acre complex.

TI sales have grown over 20-fold over the past ten years . . . from under $5,000,000 to $200,-000,000 for 1959.

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To date, almost 14,000 people at Texas Instruments are in this "Growth" picture. In addition, they are enjoying many other benefits from TI's enlightened personnel policy — company-sponsored profit sharing plan*, periodic advancement and salary reviews, educational assistance, insurance, and retirement programs.

TI offers a stimulating challenge in research, development and manufacture in geosciences, military and industrial instruments and systems, semiconductors and other electronic components. To keep its position as a leader in these fields, and to stay ahead of the ever-increasing demands of Space Age technology, more new permanent positions have been created for qualified Engineers.

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SEMICONDUCTOR-COMPONENTS DIVISION

DEVICE DEVELOPMENT—Develop new semiconductor devices; conduct experimental and theoretical studies on the effects of nuclear radiation on semiconductor materials and devices; evaluate experiments in the analysis of gases and electro-chemistry; conduct physical measurements on semiconductor surfaces; determine the effects of chemical reaction on semiconductor surfaces; studies in device stability, reliability and characterization; materials research and development including crystal growth and crystallography.
CIRCUIT DEVELOPMENT—Transistor circuit design and application; design automatic and semi-automatic test equipment.
MECHANIZATION—Design and develop high speed automatic machinery.
Please write to C. A. Besio, Dept. 1004, P. O. Box 312, Dallas, Texas

APPARATUS DIVISION

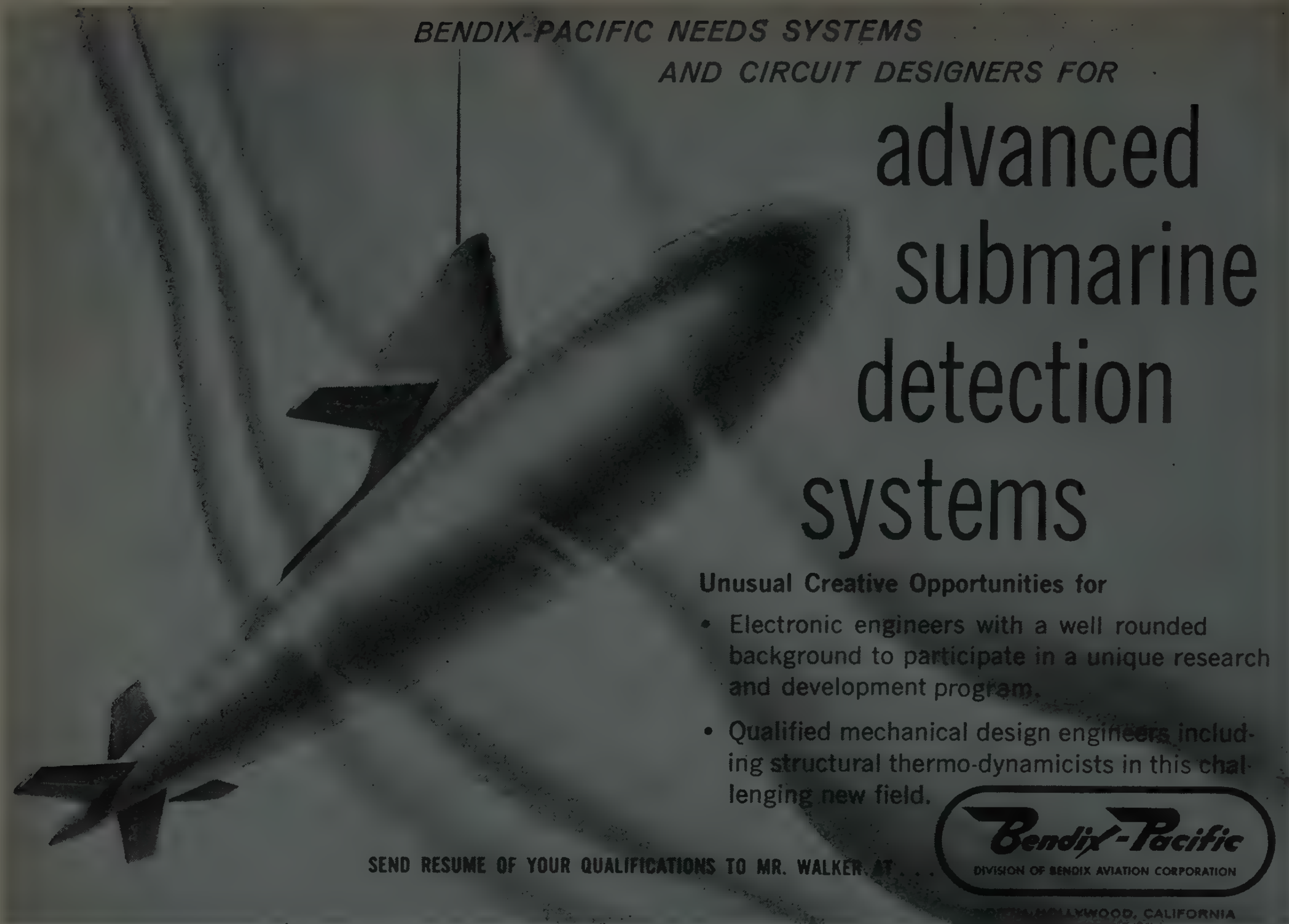
MANUFACTURING ENGINEER—To perform the planning and coordination of the manufacture of electro-mechanical/electronic systems and components on an assigned project basis; to determine action to be taken; follow-up and report successful operation of the course of action selected. BS in EE, ME or IE, with minimum 3 years experience in manufacturing processes, tooling, scheduling, and costs.
QUALITY CONTROL ENGINEER—To establish and maintain standards of quality and inspection methods for all raw materials, work in process and finished products. BS in EE, ME or IE with minimum 3 years experience in working to customer requirements, procedures, quality reports plus prevention and detection of defects in electro-mechanical apparatus.
SENIOR MICROWAVE ENGINEER—To perform applied research and development in the field of microwave and high-powered transmitter equipment including ASR transmitter and automatic performance monitoring. MS in Physics or EE with minimum 5 years experience in the field of microwave and high-powered transmitting equipment.
SENIOR ELECTRONIC ENGINEER—To conduct engineering analysis of techniques that will be incorporated into various product lines. Electronic design experience associated with the missile field involving circuit (transistor), computers, telemetry, and guidance systems design essential. MS in EE, ME or Physics with minimum 7 years experience in field of missile electronic design and systems planning and analysis.
CIRCUIT DESIGN ENGINEER—With strong instrumentation background with emphasis on circuit design. Experience in application of transistor circuits to instrumentation highly desirable although not essential. BS or MS in EE or Physics with minimum 5 years experience.
RESEARCH ANALYST—To perform industrial marketing research in the field of military and industrial electronics; requires analytical ability with imagination to foresee variables and recognize limitations and data; ability to present ideas clearly in verbal and written form. Must also be able to interpret and point out use and conclusion of statistical studies to division management. BS in ME, EE or MBA or MA in Economics.
SENIOR GUIDANCE ENGINEER—To design microwave antennas and circuit components; supervise engineering personnel in design and development of complete missile antenna and microwave systems; contribute original advancements in missile microwave and antenna concepts for proposals and system development. BS in EE or Physics with minimum of 5 years experience in stripline microwave design. Also thoroughly familiar with radiation and propagation theory.
MATHEMATICAL STATISTICIAN—To specialize in the study of noise applications; to perform systems analysis of sonar and radar product lines; to provide consulting service to other technical personnel. MS or PhD in Mathematics with minimum of 6 years experience in applied analysis of advanced mathematics.
MATHEMATICIAN—To specialize in transform calculus as applied to servo mechanisms and network analysis and continued fraction work; provide consulting services to other technical personnel. MS or PhD in Mathematics with minimum of 6 years experience in applied analysis of advanced mathematics.
Please write to John Pinkston, Professional Placement, Dept. 1004, 6000 Lemmon Avenue, Dallas 9, Texas

GEOSCIENCES AND INSTRUMENTATION DIVISION

MECHANICAL DESIGN ENGINEERS—BS or MS in ME to design small electro-mechanical mechanisms.
ELECTRICAL DESIGN ENGINEERS—BS in EE or Physics to design and construct supervisory control systems of electro-mechanical and electronic design; transistor test equipment, requiring heavy experience on electronic circuit design, preferably with transistors; digital computers with experience in detailed logical design.
MANUFACTURING ENGINEER—BS in ME or IE with experience in production, planning, production control, methods and tooling in the electronics industry.
SALES ENGINEER—BS in EE, Physics or ME with sales experience in electro-mechanical instruments.
Please write to Dave Turner, Dept. 1004, 3609 Buffalo Speedway, Houston, Texas

CENTRAL RESEARCH LABORATORY

HEAD–PHYSICS SECTION—4 to 5 years experience in semiconductor physics and proven ability to direct a variety of technical projects. Responsible for directing work on the measurement and understanding of electrical, thermal, magnetic, optical, and transport properties of semiconductors. Educational requirement is PhD in Physics.
HEAD–DEVICE SECTION—4 to 5 years experience in semiconductors plus experience in group leadership and proven ability to supervise a variety of technical projects. Will be responsible for directing work on design, fabrication and evaluation of new solid state devices. Educational requirement is MS or PhD in either Physics or EE.
SOLID STATE THEORIST—Responsible for the understanding and interpretation of the physical properties of semiconductors and other solid state materials. Educational requirements: PhD in Physics with concentration in quantum mechanics. Solid state experience desirable but not necessary.
DEVICE THEORIST—Responsible for the design of new solid state devices and interpretation of their characteristics in terms of physical and fabrication parameters. Educational requirement is PhD in Physics or EE, or MS with 2 to 3 years experience in solid state device theory.
SEMICONDUCTOR TECHNOLOGY—Responsible for the design and interpretation of experiments on the technology of semiconductors, including impurity diffusion and alloying. Educational requirement is PhD in Physical Chemistry or Metallurgy. Experience requirement: 3 to 4 years experience in semiconductor technology.
THEORETICAL PHYSICIST—2 to 3 years experience in electron or nuclear magnetic resonance with interest and background to perform theoretical analysis of EMR and NMR to develop possible new types of magnetometers or to make significant improvement in present types. Sufficient experimental background and interest to assist in translating theoretical results into experimental projects.
PHYSICISTS—Either MS or PhD with 1 year minimum experience in the fields of superconductivity and low temperature physics. Should be acquainted with conventional techniques of transferring and handling liquid helium and designing circuits and instrumentation for studies in this area.
Please write to A. E. Prescott, Dept 1004, P. O. Box 1079, Dallas, Texas



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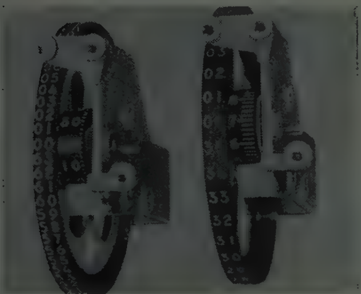
(a Division of the
Permanent Employment Agency)
825 San Antonio Rd.
Palo Alto, Calif.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(*Continued from page 178A*)

force with a 3 amperes 125 vac UL rating. Type S-MK has under 6 ounces actuating force and UL rating of 1 ampere 125 vac. Shaft travel is 5/32±1/64 inch, shaft diameters 0.250 inch and 0.187 inch, shaft lengths in increments of 1/16 inch and shaft trim is available with EIA standard slots, flats or slotted and knurled shafts.

Precision Counters



A new line of simplified design precision counters which completely eliminates transfer masks or shades and has no interrupted gearing is being offered by **Chicago Dynamic Industries, Inc., Precision Products Div.,** 1725 Diversey Blvd., Chicago 14, Ill. Series AD-1 counts hours, degrees, mils, minutes, and so forth, and returns to zero, then repeats. Because these units do not count in multiples of 10, they are ideal for applications where the counter must repeat from zero with continued rotation after a count other than 99,999,999, and so forth, such as 359 degrees, 6300 mils, 23 hours, 59 minutes, etc. Type 1040 degree counters read through 359.9° to zero and repeat with continued rotation. Type 1400 mil counters read through 6399 mils to zero and repeat with continued rotation. Both types are bi-directional and add with clockwise rotation of the input shaft. Both types have an operating temperature range −60°F to +165°F and meet MIL-E-16400-B and applicable parts of MIL-STD-167.

Coatings Booklet

"How to Use HumiSeal Protective Surface Coatings in Electronic Applications" is the subject of a 20-page booklet just released by **Columbia Technical Corp.,** 61-05 Thirty-first Ave., Woodside 77, N. Y. Filled with many useful ideas, this booklet covers such phases of applying humidity-proof protective surface coatings as conventional dipping procedures and what to do for dipping, draining and air-drying and curing. It also covers such subjects as vacuum impregnation, spray coating and masking, silk screen coating, roller coating as well as 7 other informative subjects. Six typical examples of spraying procedures

(*Continued on page 184A*)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 183A)

are given in step-by-step descriptions of each operation. Valuable charts and slide rule settings are also included. A copy of this booklet can be secured by writing to the manufacturer.

Miniaturized Special Purpose Receivers

Nems-Clarke Co., a division of Vitro Corp. of America, 919 Jesup Blair Dr., Silver Spring, Md., announces two new special purpose receivers, Types 1905 and 1906. These two equipments were accomplished through employment of solid state devices, miniaturized components, and the latest repackaging techniques.

Standard rack mounting size is 19 wide by 8¾ inches high. Types 1905 and 1906 are less than half this size with panels 19 wide by 3½ inches high by a maximum of 15 inches deep. A weight reduction of approximately 50% is also realized.

In addition, a greater frequency range coverage of 30 to 260 mc. Two bands are employed; one of 30 to 60 megacycles and the other 60 to 260 mc.

Type 1905 reception is AM and CW, and Type 1906 reception is FM, AM, and

(Continued on page 186A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 184A)

CW. The tuners in these receivers are designed to produce an extremely low noise figure and incorporate practical tuning structures capable of tuning 30 to 260 mc, with uniform performance over the band. The first RF stage employs a planar triode to assure that the noise figure of 6 db is not exceeded at any frequency.

Type 1905 sells for $2,000.00, and Type 1906 sells for $2,250.00.

Tracking Antenna

The General Bronze Corp., Garden City, N. Y., announced today that **GB Electronics,** its Valley Stream subsidiary, was building a new space vehicle tracking antenna.

The new antenna has been purchased by the National Aeronautics and Space Administration (NASA). It will be installed at the Wallops Island test site, Va., in early Spring 1960. It will cost under $250,000, approximately one-half the cost of the tracking antennas now in use.

The lightweight 40 foot array antenna, currently under construction, will replace the 60 foot dish paraboloid and can be installed and erected with minimum cost.

The new antenna moves in azimuth and elevation. It is equipped with 33 endfire elements. It can be built at half the cost and with half the manpower previously required. It is claimed that it can be installed and maintained at half the general financial outlay without any loss of fidelity from the larger, heavier and bulkier antennas.

(Continued on page 188A)

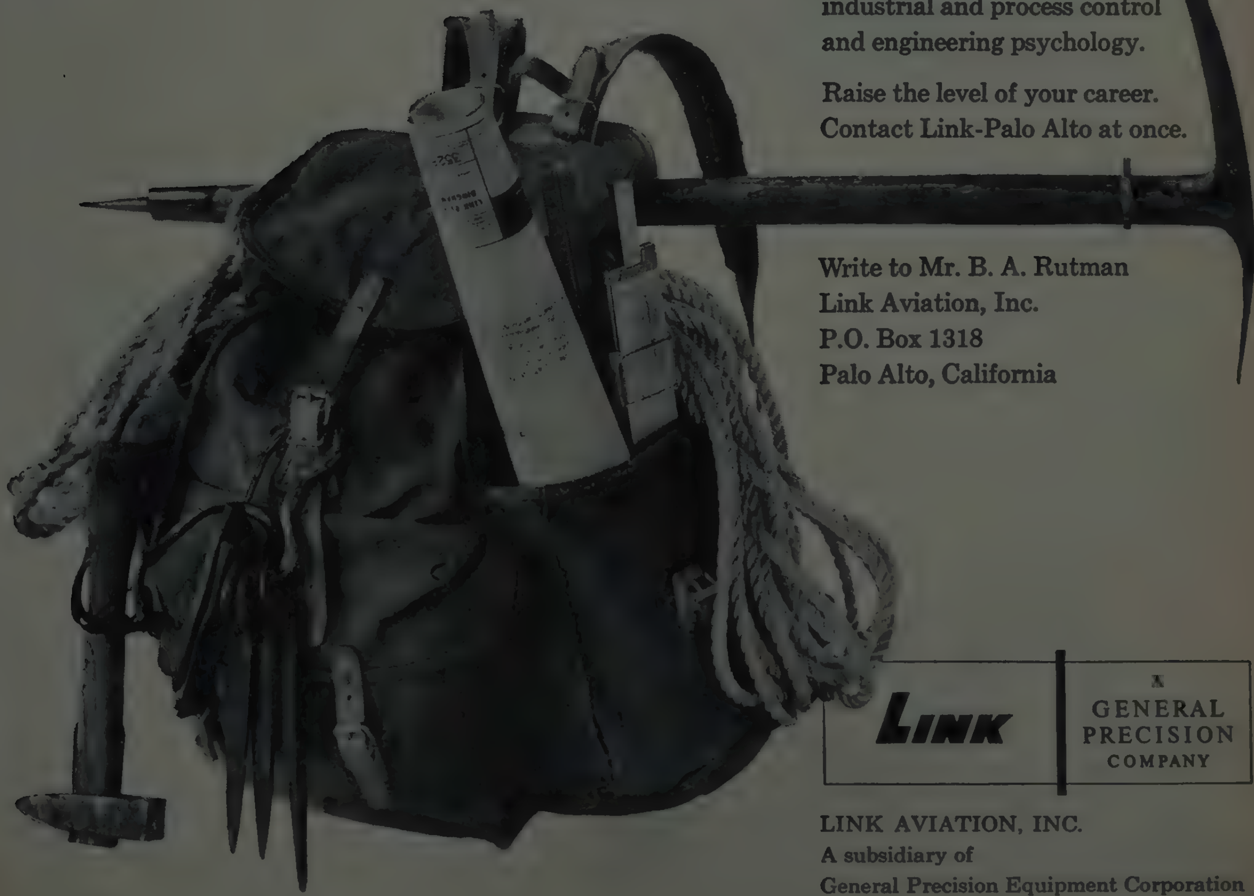
ENGINEERS REACH THE SUMMIT AT LINK–PALO ALTO

The career-climb is easier . . . and there's more room at the top . . . at Link Aviation's Research & Development Laboratory at Palo Alto. The professional atmosphere here is built on policies which give engineering talent room to expand—reward it when it does.

Link-Palo Alto offers a diversity of work assignments and is expanding rapidly to serve additional commercial and military customers. This expansion means additional engineering and support personnel, new facilities, greater professional growth.

Link now has staff openings for ambitious engineers with experience in: analog or digital computer components and systems; missile systems analysis; radar simulation; industrial and process control and engineering psychology.

Raise the level of your career. Contact Link-Palo Alto at once.



Write to Mr. B. A. Rutman
Link Aviation, Inc.
P.O. Box 1318
Palo Alto, California

LINK | A GENERAL PRECISION COMPANY

LINK AVIATION, INC.
A subsidiary of
General Precision Equipment Corporation

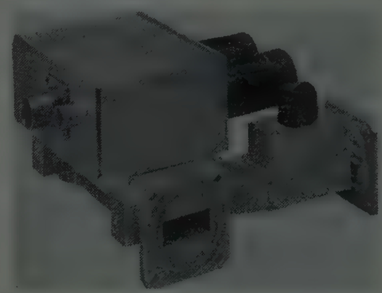
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 186A)

Matched Mixer-Preamplifier

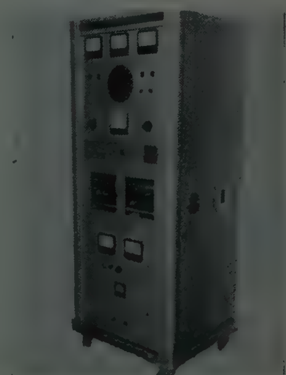
This addition to the line of matched microwave-preamplifier units by **LEL, Inc.**, 380 Oak St., Copiague, L. I., N. Y. covers the 8.5 to 9.6 kmc range, has a minimum gain of 25 db, a maximum noise figure of 7.5 db, and a 50 ohm IF output at 30 or 60 mc. It is available with or without an integral variable attenuator in the LO arm.



The MMX-2 is a mechanically and electrically integrated unit which will provide optimum receiver performance and enable the user to avoid the electrical problems which often arise from the use of an unmatched assembly.

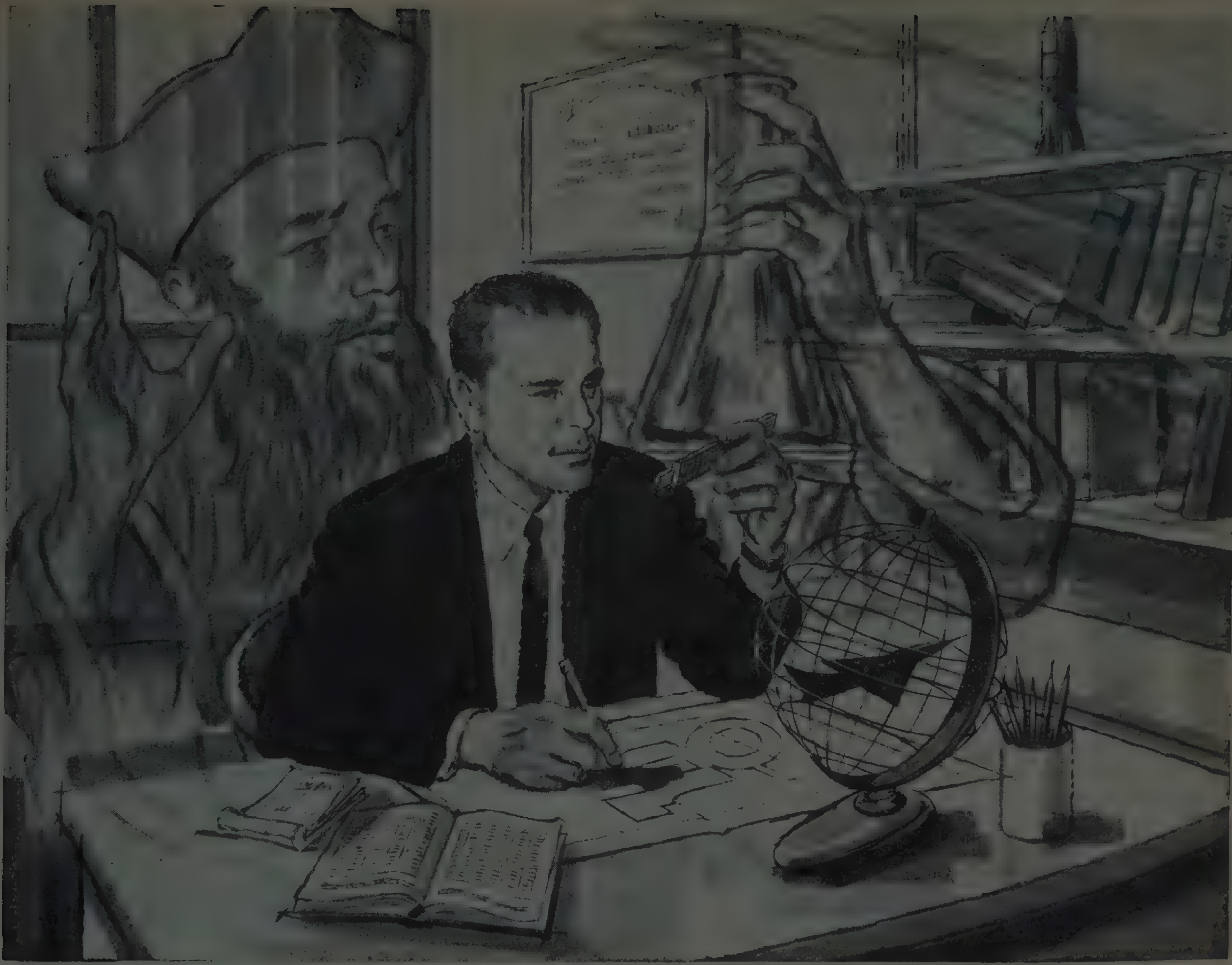
RF Signal Sources

A new high power RF signal source series, the Model 700, is now available to the radar and microwave industry from **Burmac Electronics Co., Inc.**, 142 S. Long Beach Rd., Rockville Centre, N. Y. The series is available for CW pulse or dual modes of operation.



Klystrons, pulse magnetrons, CW magnetrons or traveling wave tubes are incorporated as generator elements in the Model 700 lines. Each unit also features built-in RF power monitors, filament regulators, band switching, generator tube protective circuits, vacuum of semi-conductor power supplies, personnel circuit protection and complete control function indicators.

(Continued on page 192A)



NEWS New Products

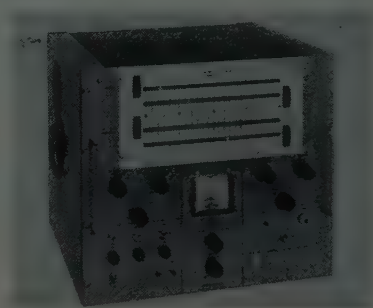
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 188A)

This series incorporates optimum wave shape and circuit parameters to insure proper operation of the RF generator tube and is available from the ultra high frequency through and including the K band microwave frequency spectrum. Antenna measurements, component testing and auxillary transmitter functions are typical applications for the Model 700 series RF signal sources. Additional information and application assistance may be obtained by writing the firm.

Microwave Oscillators

A new series of swept microwave oscillators covering the 1 to 18 kmc frequency range is now available from **Alfred Electronics,** 897 Commercial St., Palo Alto, Calif.



Alfred's series 620 models, which offer the broadest frequency range currently available, provide electronic sweep of RF output, or extremely stable CW operation.

All models feature linear frequency sweep coverage over all or part of each band for rapid evaluation of reflection coefficient, gain, attenuation and other network transfer characteristics.

Series 620 oscillators offer these two features; Two adjustable frequency markers for convenient calibration of oscilloscopes or recorders. Markers save valuable test time by indicating either band limits or intermediate frequency values. A 0.5 microsecond rise and fall response to AM—equivalent to a 2 megacycle band pass.

Frequency range, markers and sweep time can be seen at a glance, no computing is required.

For complete details, please write to the firm.

(Continued on page 194A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 192A)

Micro-Miniature Circuit Wafers

A complete line of custom and standard micro-element wafers, for both experimental and production requirements in micro-miniature circuitry, has been announced by **Zenith Optical Laboratory,** 1940 Great Neck Rd., Copiague, L. I., N. Y.

The wafers, fabricated from high alumina ceramic, steatite, glass or quartz to

(Continued on page 196A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 194A)

suit requirements, can be supplied in thicknesses down to 10 mils, less on special order. Units are drilled, ground and finished, to specifications, for end or sub-strate applications, with hole sizes from 10 mils. Tolerances on hole diameters, slots, channels and edge notches, the manufacturer states, are held to within 0.0002 inch. Where desired, wafer surfaces can be finished to precise optical tolerances.

In addition to custom wafers in a wide variety of materials, the company's line also includes both end and sub-strate units fabricated to the tentative specifications established by the RCA-Signal Corps micro-miniaturization program.

The close tolerances to which both custom and standard wafers are finished, the company points out, have been made possible through use of precision optical techniques combined with a highly developed ultrasonics machining process, which permits previously unobtainable precision and manufacturing flexibility, and allows intricate shapes and orifices to be faithfully and economically reproduced in brittle and hardened materials. In this process the tool is never in contact with the wafer material; consequently chipping, heating, stressing and distortion of the work is eliminated.

For experimental or prototype requirements, Zenith offers a custom finishing service.

Coaxial Stub Tuners

Empire Devices Products Corp., Amsterdam, N. Y., has a new line of broadband coaxial stub tuners which consist of a length of $\frac{7}{8}$ inch concentric line with one, two or three short-circuited variable length stubs at right angles to the main line. These stubs, in turn, are axially separated by $\frac{1}{2}$ or 3 inch—depending on frequency range—and each stub is a sliding tube with tempered beryllium contact springs.

In operation, a sliding adjustment of the tube places a short directly across the stub, thus providing the susceptance needed. Knurled locking nuts hold the tubes firmly in place once the optimum tuning position has been obtained, to prevent inadvertent mis-adjustment.

Stub tuners may be used to optimize the power output of microwave oscillators

(Continued on page 198A)

CIRCUIT DEVELOPMENT ENGINEER

your future:
a challenging opportunity with an industry leader

At Texas Instruments, your future is filled with specific, stimulating growth assignments in evaluating and characterizing transistors and special semiconductor devices. You'll participate in such transistorization projects as:

- **AM, FM, and TV receivers**
- **audio and video, i-f and r-f amplifiers**
- **hi-fi and electronic organs**
- **nonlinear and switching circuits**
- **computer system logic**
- **servo and power amplifiers**

With TI... receive liberal company-paid benefits, including profit sharing *(last year 15% of base salary)* ... enjoy premium living in a moderate climate with excellent neighborhoods, schools and shopping facilities.

Interviews will be held in your area soon. If you have an Electrical Engineering degree and/or knowledge of transistor circuitry, please send a resume to:

H. C. Laur, Dept. 200-E-PI
(for immediate Eastern appointment)
1141 E. Jersey Street, Elizabeth, New Jersey

C. A. Besio, Dept. 200-PI

TEXAS INSTRUMENTS
INCORPORATED
SEMICONDUCTOR - COMPONENTS DIVISION
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New Problems in Advanced

RESEARCH AND DEVELOPMENT

Challenge Engineers at

GENERAL DYNAMICS
Electric Boat Division

Pioneer in design and development of nuclear powered submarines, Electric Boat Division is embarked upon a broad program of expansion and diversification in advanced technological areas.

One project now underway is a complex simulator for training Polaris weapon system crews in submarine control, navigation and missile firing. This trainer, housed in its own building, uses a DC analog computer to provide realistic response to trainee actions and will permit practice of normal operations as well as emergency drills which may be too dangerous to perform in operating submarines.

Other stimulating work areas include large control systems (140-foot precise radio telescope, world's largest wind tunnel, submarine systems); training equipment (simulators and trainers for missiles, submarines and other weapons systems); advanced submarine development (integrated control systems for sonar, navigation, missile launching and weapons guidance).

Immediate Opportunities in:

SYSTEMS

EE, ME or Physics degree required. Responsible for conceptual engineering and systems analysis of large complex devices employing a combination of electrical, electronic, electromechanical, hydraulic and pneumatic systems. Should be familiar with servomechanisms theory, experienced in use of analog or digital computers as a design tool, and have a good grasp of mathematics. Will work on proposal preparations, feasibility studies and execution of hardware contracts.

COMPUTERS

Responsible for conceptual engineering and programming of special purpose digital and analog computers. Should be familiar with system engineering, experienced in programming and check systems for both analog and digital computers, with good grasp of simulation techniques. Requires EE, Physics or Mathematics degree.

CIRCUITS

Responsible for conceptual and production engineering of electronic equipment. Familiar with servomechanisms and analog computer theory. Experienced in use of semiconductors, magnetic amplifiers and vacuum tube circuit elements; good grasp of mathematics; EE or Physics degree.

OPERATIONS RESEARCH

Ph.D. in physical sciences required. To be responsible for operations research studies of submarine and anti-submarine weapons systems.

SERVOMECHANISMS

For engineering design of servomechanisms in both the instrument and multiple horsepower class. Will interpret performance specifications and be responsible for design of a system in accordance with the specifications, including stability studies, and the calculation of other performance criteria.

Electric Boat Division is located on the beautiful Connecticut shore near New London. Situated half way between Boston and New York City, it affords gracious New England living and year round recreation for you and your family.

To arrange convenient appointment, write in confidence to James P. O'Brien, Technical Employment Supervisor.

GENERAL DYNAMICS
Electric Boat Division
GROTON CONNECTICUT

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

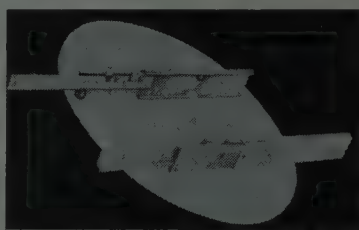
(Continued from page 196A)

by matching the impedance of the source to the load; to tune out reflections in a coaxial transmission system; to maintain a low VSWR on a transmission line for maximum power transfer with a system; as an impedance transformer; or to provide a DC return for crystal holders or other devices where DC returns are needed.

A total of 6 types of tuners are available. Input and output connectors are Type "N" male and female. Tuners cover the frequency ranges from 200 to 1000 mc and from 1000 to 10,000 mc, will withstand severe shock and vibration, and are designed to insure accurate impedance matching over the entire frequency range. A mounting support is available for laboratory use. Request catalog ST-359.

Low Cost Slide

Grant Pulley & Hardware Corp., High St., W. Nyack, N. Y., announces the availability of their newest slide—the 324 "Budgeteer."

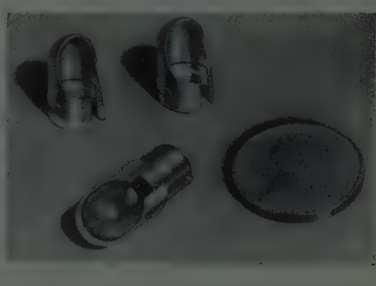


The 324 offers a number of intrinsic features normally considered as part of the most expensive slides.

Tests have indicated that this 3 section steel ball bearing slide is capable of high performance. Features such as extended position locking, quick disconnect mechanism, MIL spec approval, 150 pound load rating and others, add to its value.

Instrument Lamp Shields

Two new all-metal lamp shields for the T-3¼ lamp used in pilot lights and other instrument lighting are now in production, and immediate deliveries are assured by



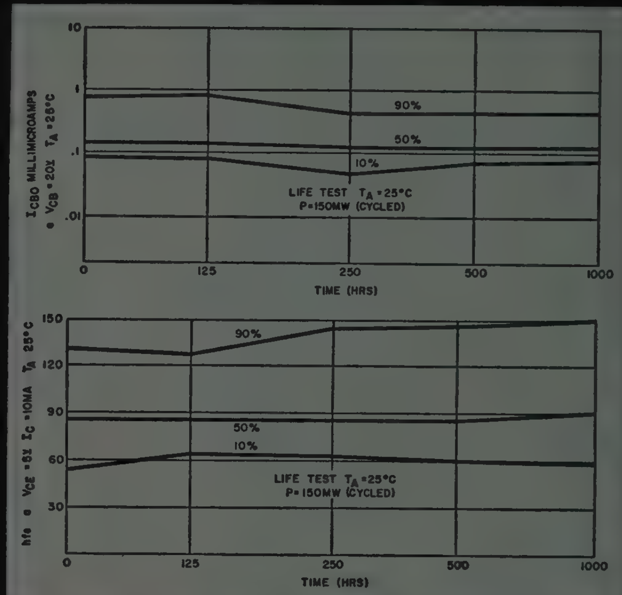
Amaton Electronics Hardware Co., 88 Drake Ave., New Rochelle, N. Y.

These shields are of spring-type brass,

(Continued on page 202A)

New life test data prove superior

Magnified photo of silicon transistor showing Fixed Bed Construction. All parts are firmly fastened, with no suspended parts except wire lead. Transistor reacts as a solid block in resisting shock and vibration.



Charts show extreme stability of performance throughout 1000 hours of life for beta and I_{CBO}. Test conditions were 150 mw at 25°C, 200°C storage and 25 mw at 125°C. Drift rates were substantially the same under all conditions.

New NPN Tetrodes: Higher gain at high temperature and low current

LARGE QUANTITIES OF TYPES 3N36 AND 3N37 TESTED AND PROVED, HIGH RELIABILITY THE RESULT OF TWO YEARS OF MANUFACTURING EXPERIENCE*

Test	Results	% Survival
Mechanical Reliability		
3-ft drop-shock (2500 G's. Mil St'd calls for 500G's)	2 out of 595 did not survive	99.66
Temperature cycling (−55°C to 100°C)	1 out of 375 did not survive	99.78
Life Test Reliability		
Cycled power @ 50 mw (device rated at 30 mw)	6 out of 500 exceeded parameter limits at 1000 hours	98.8
Oven @ 85°C	17 out of 500 exceeded parameter limits at 1000 hours	96.8
Shelf	No parameter failures of 500 units at 1000 hours	100.0

*General Electric's rigid standards call for only a slight shift in parameters to be a "failure." Many of these "failures" are still within EIA limits.

Here are two new germanium transistors that operate on lower voltages, require less current and are more rugged (see box below) than any other transistors that perform a like function. Furthermore, they deliver a high and constant gain at various voltages and at low power dissipation levels. Therefore, they are not only useful at high temperatures, but they also simplify circuit design and eliminate the need for close voltage regulation.

Features: Maximum gain at 1 ma, 5 volts or 5 mw. Flat gain noise factor from 1 ma to 5 ma. *Where to use them:* Mobile communications (made possible the first transistorized portable receiver). Wide band amplifier, oscillator and switching applications for radar and video at frequencies to 200 mc. *Availability:* Now . . . from your General Electric Semiconductor Sales Representative and in stock at your G-E Semiconductor Distributor's.

Absolute Maximum Ratings (25°C)	2N36	2N37	
Collector voltage to base 1 or base 2 (V_{CB})	+7	+7	V
Emitter to base 1 or base 2 (V_{EB})	+2	+2	V
Collector current (I_C)	+20	+20	ma
Emitter current (I_E)	−20	−20	ma
Base 2 current (I_{B2})	2	2	ma
Total Power dissipation	30	30	mw

Electrical Characteristics (25°C)			
Output capacity (C_{ob})	2	1.5	μμf
Noise figure (NF)	11	11	db
Input impedance (h_{ie})	100-j27	80-j10	ohms
Current transfer ratio (h_{fe})	$2.2\angle -81°$	$1.1\angle -100°$	
Common base cutoff frequency (f_{ab})	50 MIN.	90 MIN.	mc
Common Emitter power gain (G_e)	11.5	9	db
Measurement frequency	60	150	mc

stability of G-E silicon transistors

Uniform characteristics out to 1000 hours exhibited by silicon transistors featuring Fixed Bed Construction

Comprehensive tests performed on General Electric silicon transistors show remarkably stable performance throughout 1000 hours of operation at high temperatures. Each test was run on seven lots of fifty Type 2N337 or 2N338 transistors (part of the series 2N332 through 339). These are the results:

> 350 units were given a 150 mw operating test at 25°C.
>
> Only two units exceeded parameter limits, a successful performance rate of 99.4 percent.
>
> 350 units were given a 200°C storage test.
>
> Only three units exceeded parameter limits, a successful performance rate of 99.1 percent.

Fixed Bed Construction, plus stabilized processing makes these results possible. No fluxes, resins or solders are used — only a gold alloy which forms an integral bond between all parts.

Besides the demonstrated electrical characteristics, General Electric's silicon transistors can absorb physical punishment far beyond normal specifications. All parts are solidly fixed together and react as a solid block in resisting shock and vibration. Test units have been fired from a shotgun, struck with a golf club and rattled freely in an auto hubcap for 700 miles—and worked afterward.

Electrically and mechanically, this series of transistors is the most thoroughly tested and proved today—your assurance of high stability and reliability. Call your General Electric Semiconductor Representative for further details.

ABSOLUTE MAXIMUM RATINGS AT 25°C

	2N332-6	2N337-8	
Collector to base voltage	45	45	volts
Emitter to base voltage	1	1	volt
Collector current	25	20	ma
Collector power dissipation	150	125	mw
Operating temperature	−65°C to 175°C	−65° to 150°C	

Now available—4 new NPN alloy transistors

Four new germanium switching transistors, made by the highly controllable NPN alloying process, are now being warehoused by General Electric and its distributors. The four transistors, Types 2N634, -5, -6 and 2N388, feature extremely consistent parameters. I_{CO} for instance, multiplies up in a normal fashion, so that higher temperature I_{CO} may be predicted from low temperature readings.

The transistors provide 150 mw power dissipation. They are useful in emitter-follower applications in computers, high current flip-flops, and are ideal as complementary devices to PNP computer transistors, such as the 2N396.

Absolute Maximum Ratings at 25°C

Collector to base voltage	20 volts
Emitter to base voltage	15 volts
Collector to emitter voltage	20 volts
Collector current	300 ma
Base current	50 ma
Emitter current	300 ma
Storage temperature	85°C to —65°C
Operating junction temperature	85°C
Power dissipation	150 mw

For complete information call your General Electric Semiconductor Sales Representative, your G-E Semiconductor Distributor, or write Section S54109, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York.

GENERAL ELECTRIC

Semiconductor Products Dept., Syracuse, New York

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 198A)

cadmium plated, and fit directly on the glass portion of the T-3¼ lamp. They come in two styles, straight and flared, with aperture for controlling the lamp beam.

Request for information on the T-3¼ lamp shield should be directed to the firm.

Analog-Digital Converters

Kearfott Company, Inc., 1500 Main Ave., Clifton, N. J., a subsidiary of General Precision Equipment Corp., announced the availability of rugged shaft position-to-digital converters suitable for high and low temperature environments with high shock and vibration resistance such as that associated with missile applications.

Kearfott ADAC (Analog-Digital Converters) are available for applications including latitude, azimuth or conventional angular shaft displacement conversion and for decimal count conversion and so forth In addition, combination counter-converter assemblies providing both visual and electrical digital readout are available.

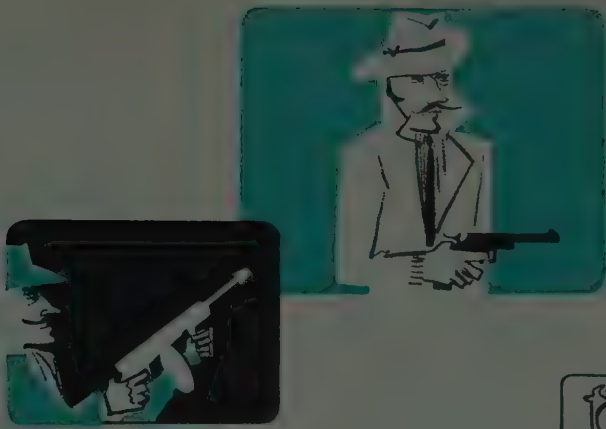
The exclusive drum design of Kearfott converters provides for large conversion capacity in the smallest possible size. Typical units provide for non-ambiguous conversion up to 2^{16} in a unit diameter less than 1.5 inches and length of 1 .15/16 inches.

Other features include Mechanical Accuracy: Code transition point within ½ bit of true angular shaft position. Low and High Temperature: Fully operational from −80°F to 350°F. Shock: Withstands 18 shocks in 3 orthogonal planes. Vibration: No skips during 5–500 cps vibration at ±10 g's. Acceleration: No skips during radial acceleration up to ±7.5 g's. Life: 1000 hours (minimum) at 82 RPM continuous rotation.

Limit Switch

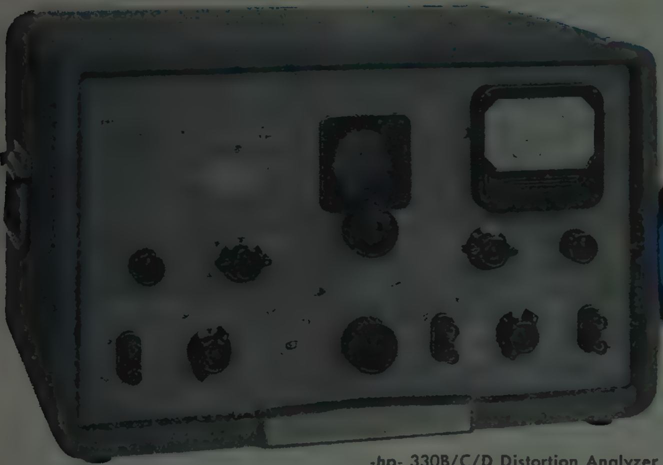
A new magnetic limit switch which has no moving parts and which acts on proximity of its two sensing elements, rather than actual physical contact, has been intro-

(Continued on page 208A)



Swift, sure

DISTORTION READINGS



-hp- 330B/C/D Distortion Analyzer

20 cps to 20 KC

Measure distortions as low as 0.1%
Measure noise on voltages as small as 100 μv
High sensitivity, high stability
Wide band 20 db gain amplifier
Oscilloscope terminals; built-in VTVM

-hp- 330B Distortion Analyzer is a basic instrument universally used to measure total audio distortion, voltage level, power output, gain, total AM carrier distortion, noise and hum level and audio signal frequencies.

Model 330B consists of a frequency selective amplifier, a regulated power supply and a VTVM. The amplifier operates with a resistance-tuned circuit to provide almost infinite attenuation of the fundamental while passing harmonic frequencies at normal gain. Negative feedback minimizes distortion and insures uniform response and stability. The VTVM is used to set the load and measure the value of harmonic voltages, thus providing a direct reading of total distortion. The VTVM may also be used separately.

For FM broadcasters, *-hp-* 330C is offered. Similar to 330B, this instrument has a meter with VU ballistic characteristics meeting F.C.C. requirements and a VTVM frequency range of 10 cps to 60 KC.

For FM-AM broadcasters, *-hp-* 330D is available. This instrument is similar to *-hp-* 330C except for addition of an AM detector covering 500 KC to 60 MC.

Details from your -hp- representative, or write direct

HEWLETT-PACKARD COMPANY

4819D PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
CABLE "HEWPACK" • DAVENPORT 5-4451
Field Engineers in all Principal Areas

SPECIFICATIONS

Distortion Measurement: 20 cps to 20 KC.

Dial Calibration Accuracy: ±2% full range.

Elimination Characteristics: Reduces fundamental frequency more than 99.9%.

Accuracy: ±3% full scale at distortion levels of 0.5%.

Sensitivity: Distortion levels of 0.3% are measured full scale. Accurate readings on 0.1% levels.

Input Impedance: 200,000 ohms, 40 $\mu\mu$f shunt.

Required Input: 1 v RMS.

Voltmeter: Nine 10 db ranges, 0.03 to 300 v. Full scale sensitivity all ranges.

Noise Measurement: 300 μv full scale. Coverage 10 cps to 20 KC.

Oscilloscope Terminals: 75 db max. gain from AF input to terminals.

Price: -hp- 330B, $410.00 (cabinet), -hp- 330C, $440.00 (cabinet), -hp- 330D, $500.00 (cabinet), (Rack models $15.00 less).

Data subject to change without notice.
Prices f.o.b. factory.

hp now has a 200 KC 'scope for $435! Seen it?

Styroflex® *Coaxial Cable*

is a vital part of the Air Force Automatic-Tracking Antenna System!

The powerful TLM-18 telemetry antenna now in service at the Air Force Missile Center, Cape Canaveral, Fla., is used for the automatic tracking of missiles and earth satellites. This huge "mechanical ear," specifically designed by Radiation, Inc., Melbourne, Fla., has an effective data reception range of over 1000 miles.

One of the key parts of this highly sensitive device is the ⅞", 50 ohm, aluminum sheathed Styroflex® coaxial cable that links the 60-foot parabolic reflector to the receivers. The task of carrying missile-to-earth signals from the antenna to the control building demands a low-loss, high frequency cable with a high signal to noise ratio.

The remarkable characteristics of Styroflex® cable not only meet these rigid specifications but also have extra operational advantages, including long operating life under severe conditions and stable electrical properties during wide temperature variations.

Styroflex® coaxial cable has earned an outstanding record for these qualities in a variety of industrial, mass communication and telemetering applications. Perhaps this cable can answer your particular high frequency cable problem. We invite your inquiry.

PHELPS DODGE COPPER PRODUCTS
CORPORATION
300 Park Avenue, New York 22, N.Y.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

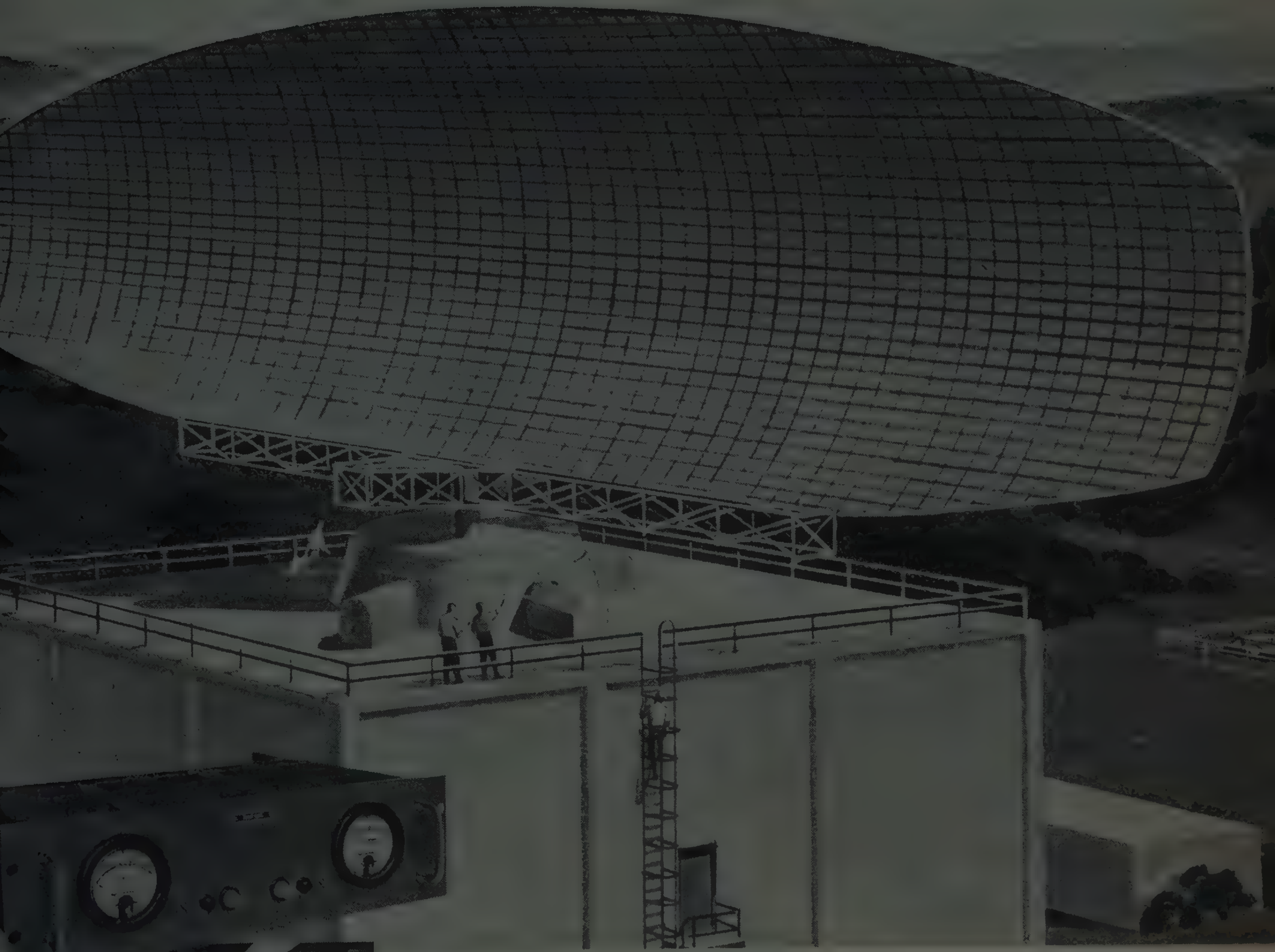
(Continued from page 202A)

duced by **Consolidated Controls Corp.**, Bethel, Conn., a subsidiary of Consolidated Diesel Electric Corporation.

Known as the Amplet magnetic limit switch, the device is seen by its manufacturer as suited to those automation applications where precise control of the relative motion between two parts of a machine is required. Typical applications include limiting cuts or traverse on such machine tools as shapers, planers and drill presses; stopping conveyors at pre-determined positions; continuous sequencing and

(Continued on page 214A)

Lambda Power Supplies specified for newest radar installation



"Off-the-shelf" Lambda power supplies —modified only with special panels, MIL meters and tubes—will be part of the complex radar equipment housed in the 85-foot tower at Thomasville, Alabama, one of four identical installations.

Meet MIL-E 4158 environmental test requirements

Sperry Gyroscope Co., operating under the technical guidance of the Rome (N.Y.) Air Development Center, is producing the new SAGE radar equipment (AN/FPS-35). The power supplies employed to power transmitters and receivers must be able to pass stringent tests.

Sperry's choice: Lambda's COM-PAK,® already widely used as a component in many rocket and missile programs.

All Lambda stock industrial power supplies are made to MIL quality and *guaranteed for five years.* They are pictured and described in a new 32-page catalog. Write for your copy.

LAMBDA ELECTRONICS CORP.

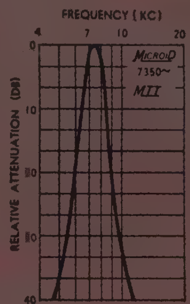
11-11 131 STREET • COLLEGE POINT 56, NEW YORK

INDEPENDENCE 1-8500 CABLE ADDRESS: LAMBDATRON, NEW YORK

SPACE SHRINKERS

MICROIDS AND MONKEYS— Burnell & Co. welcomes the assistance of their simian friends in the task of gathering data vital to space shrinking. By shrinking toroids, filters and related networks for guidance and communication systems, Burnell helps space vehicles carry bigger payloads — more instrumentation, animals — eventually man. Typical of our accomplishments is the MTT MICROID® telemetering band pass filter. Significantly, the combined weight of 23 MICROIDS — plus the monkey — is less than the single non-miniaturized telemetering band pass filter pictured here. MICROID band width is 15% at 3 db + 60% −40% at 40 db. Frequency coverage is from .4 kcs to 70 kcs.

Sizes	
Channels 1-6	2x27/32x1/2
Channels 7-10	1-5/16x11/16x11/16
Channels 11-18	15/16x19/32x1/2
Alternates A-E	15/16x19/32x1/2



Write for Filter Bulletin MTT 23.

2/3 actual size

Burnell & Co., Inc.

PIONEERS IN microminiaturization OF TOROIDS, FILTERS AND RELATED NETWORKS

EASTERN DIVISION
DEPT. P-13
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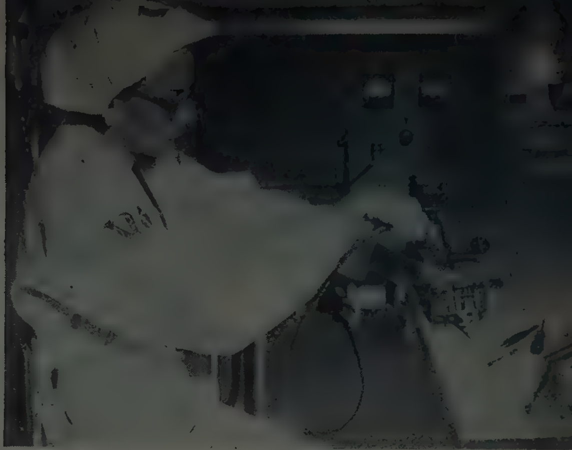
PELHAM, N. Y.
PELHAM 8-5000
TELETYPE PELHAM 3633

PACIFIC DIVISION
DEPT. P-13
720 MISSION ST.
SOUTH PASADENA, CAL.
RYAN 1-2841
TELETYPE: PASACAL 7578



Vacuum equipment at each of the 240 individual assembly benches helps insure product reliability.

The unseen enemy

How Summers Gyroscope guards against the invisible anti-missile

There is an invisible enemy operating in many plants producing the missile components, flight instruments, gyroscopes and other hyper-sensitive devices on which much of America's power for peace depends. The strength of this unseen foe is potentially as great as that of any anti-missile missile.

Destroyer Of Standards

This reliability destroying, efficiency reducing enemy is dust, lint and other foreign matter. The slightest air borne contaminant coming to rest unseen on sensitive mechanisms during assembly can cause serious, even fatal deviations in performance. Production was often slowed until tests showed the system to be free of dust.

Dust Moved But Not Removed

To combat the dust dilemma at the Summers Gyroscope Co. plant in Santa Monica, California, personnel donned lint free jackets and hats — walked to their work benches in shoe bags. Temperature and humidity were controlled in an attempt to achieve an environment completely free of every possible contaminant ranging from stray hairs to perspiration. However, these precautions proved only partially successful when it was found that a manual dust gathering system in the final assembly "clean room" actually recirculated dust instead of removing it.

Double Duty Production Tool

For a solution to the dust menace, Summers called upon U.S. Hoffman Machinery Corp., pioneers in the use of air as a production tool. Hoffman engineers installed a permanent stationary vacuum cleaning system which provided for necessary cleaning operations at all of the 240 individual work benches in the 12,000 square foot final assembly area. Standard attachments made this same system available for cleaning overhead and under foot, all over the plant.

Before And After

Prior to the installation of the Hoffman stationary system, relative cleanliness tests were conducted. A microscopic analysis of slides revealed lint, dust and other foreign matter in excess of quantities allowable to maintain Summers' high precision standards. A short time after the Hoffman equipment was placed in operation, the same tests showed a truly dust free "clean room".

How It Operates

Heart of the stationary cleaning system at the Summers plant is a 60 hp Hoffman centrifugal exhauster producing the vacuum. A centrally located dust separator outside the assembly rooms collects the material with large filtering area insuring thorough cleaning of the air. Hoses for cleaning are inserted into strategically located inlet valves in the piping system conveniently located throughout the areas to be vacuumed.

Benefits And Advantages

Insuring spotlessly clean work in final assembly and calibration, the Hoffman stationary vacuum system already has paid for itself. It has helped Summers Gyroscope reduce rejects, maintain high reliabilty, increase production and improve employee morale. The Hoffman system enables Summers to meet and exceed specifications in supplying inertial guidance systems, flight instruments and gyroscopes to the U. S. Air Force, U. S. Navy, the Martin Co., McDonnell Aircraft, Douglas Aircraft and the Convair Div. of General Dynamics, among others.

If you have a special cleaning problem in your plant, ask for a free engineering survey to determine the most economical Hoffman system to prevent product contamination, salvage valuable materials, insure better housekeeping and encourage operating efficiency. Write for free booklet — How Stationary Vacuum Cleaning Systems Cut Costs, Increase Plant Efficiency.

U.S. Hoffman Machinery Corp.
Dept. A-1 Air Appliance Division
103 Fourth Ave., New York 3, N. Y.

Note how the Hoffman vacuum system handles both parts cleaning, (rear) and housekeeping chores.

A final assembly area is kept dust-free by the Hoffman vacuum system.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 208A)

counting, and automatic weighing and filling.

The device consists of three parts—a probe, which is normally mounted on a stationary part of the machine being controlled; a magnetic trigger, which is mounted on a moving part of the machine or on the part being machined, and a power amplifier, which increases the power output of the probe to useful levels.

Power input to the unit at full load is seven watts of 115-volt, 60 cps AC. The output signal is 50 microamperes in the "off" condition and five watts of 24-volt dc in the "on" condition.

Because the switch makes use of only static devices, the manufacturer claims that it will not wear out and need replacement. The probe encapsulated in epoxy resin, making the unit waterproof. The trigger is a permanent magnet device.

Semiconductor Wire

The J. M. Ney Co., Maplewood Ave., Bloomfield, Conn., is now offering gold gallium (up to 2½% gallium) and gold antimony (up to 0.7% antimony) alloys for use in semiconductors. These alloys are

(Continued on page 216A)

BASIC BUILDING BLOCKS FROM KEARFOTT

Data Logging

Kearfott's broad line of test equipment includes the Scanalog 200-Scan Alarm Logging System which monitors, logs and performs an alarm function of up to 200 separate temperature, pressure, liquid level or flow transmitters. This precise data handling system is equipped with manual controls for scanning rates, automatic or manual logging, data input relating to operator, time, day, run number and type of run. 200 numbered lights correspond to specific points being maintained and provide a visual "off normal" display for operator's warning. System can be expanded to 1024 points capacity and 2000 points per second scanning rate.

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

Floated Rate Integrating Gyros

Specifically designed for missile applications, these Kearfott miniature gyros operate efficiently at unlimited altitudes. Their outstanding accuracy and performance make them superior to any comparably-sized units on the market. Hermetically sealed within a thermal jacket, these gyros are ruggedly designed and completely adaptable to production methods. Performance characteristics that are even more precise can be provided within the same dimensions.

TYPICAL CHARACTERISTICS

Mass Unbalance:
- Along Input Axis: 1.0°/ hr maximum untrimmed

Standard Deviation (short term):
- Azimuth Position: 0.05°/hr
- Vertical Position: 0.03°/hr

Drift Rate Due to Anisoelasticity
- Steady Acceleration: .015°/hr./g^2 maximum

Vibratory Acceleration:
- .008°/hr./g^2 maximum

Damping:
- Ratio of input angle to output angle is 0.2

Characteristic Time:
- .0035 seconds or less

Weight: 0.7 lbs.

Warm-Up Time:
- 10 minutes from −60°F

Life: 1000 hours minimum

BASIC BUILDING BLOCKS FROM KEARFOTT

Electrohydraulic Servo Valve

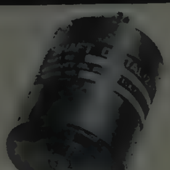
Kearfott's unique approach to electrohydraulic feedback amplification design has resulted in a high-performance miniature servo valve with just two moving parts. Ideally suited to missile, aircraft and industrial applications, these anti-clogging, 2-stage, 4-way selector valves provide high frequency response and proved reliability even with highly contaminated fluids and under conditions of extreme temperature.

TYPICAL CHARACTERISTICS

Quiescent Flow .... 0.15 gpm
Hysteresis ... 3% of rated current
Frequency Response 3 db @ 100 cps
Supply pressure....500 to 3000 psi
Temperature-Fluid & Ambient −65°F to +275°F
Flow Rate Range .... .3 to 10 gpm
Weight .... 10.5 ounces

Write for complete data.

Analog Digital Converter



20 Second Synchro

Integrator Tachometer

Kearfott | A GENERAL PRECISION COMPANY

KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.
A subsidiary of General Precision Equipment Corporation
Sales and Engineering Offices: 1500 Main Ave., Clifton, N. J.
Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 214A)

available in wire, sheet and in special shapes to customers' specifications. Ney's wire forming, stamping and machining facilities are capable of producing special shapes from sheet, wire or ribbon. Facilities for drawing all sizes of wire down to 0.0005 diameter are available (pictured above). The minimum size depends on the nature of the alloy but in most cases is about 0.001 diameter. All thicknesses of sheet down to 0.001, or slightly less, can be produced depending on the nature of the alloy.

A detailed specification bulletin on Ney's gold gallium and gold antimony alloys will be sent on request to Dept. I, The J. M. Ney Co.

Circuit Tester

Polyskop, a novel electronic test instrument for two- and four-terminal network measurements and featuring 2-channel frequency-response display, 0.5 to 400 mc frequency range, and sweep width of ±0.2 to ±50 mc, has been developed and is manufactured by **Rohde & Schwarz,** Munich, West Germany, and is now available in the United States through **Rohde & Schwarz Sales Co.** (U.S.A.), Inc., 111 Lexington Ave., Passaic, N. J.

Designated Type SWOB, Polyskop displays two separate quantities as a function of frequency over a wide band in the form of continuous curves.

Polyskop displays frequency response of voltages which, depending upon the check point on the circuit being tested, is a direct measure of attenuation, gain, linearity, matching, etc. Instantaneous indication makes this instrument suitable for alignment work and for determination of the optimum proportions of circuit elements. Range of attenuation measurement is 45 db.

(Continued on page 218A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 216A)

Maximum versatility is achieved by utilizing low-capacitance diode probes or a coaxial 50-Ω input with built-in detector to connect to the Polyskop display section. Circuits under test incorporating a detector are connected to special VLF inputs. Design of the instrument permits display of the sweep signal generator's EMF or output voltage.

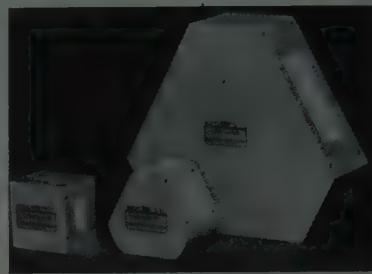
The manufacturer claims that a qualified engineer can solve problems 10 to 50 times more rapidly than when using instruments for point-by-point measurements. Representative problems involve single tuned circuits; band-pass filters; limiters; wideband amplifiers; television receivers; video amplifiers; RF amplifiers discriminators, and multi-section filters.

New Plant

Uni-Seal, Inc.'s new Garwood, N. J. plant is complete and running at full production capacity, it was announced in a joint statement by Bill Casey and Fred Dente. The newly-formed company is now able to make delivery on its wide line of transistor mounts, multi-headers, complete header and cover assemblies, individual terminals, crystal bases, diode housings, condenser and seals, and terminal strips.

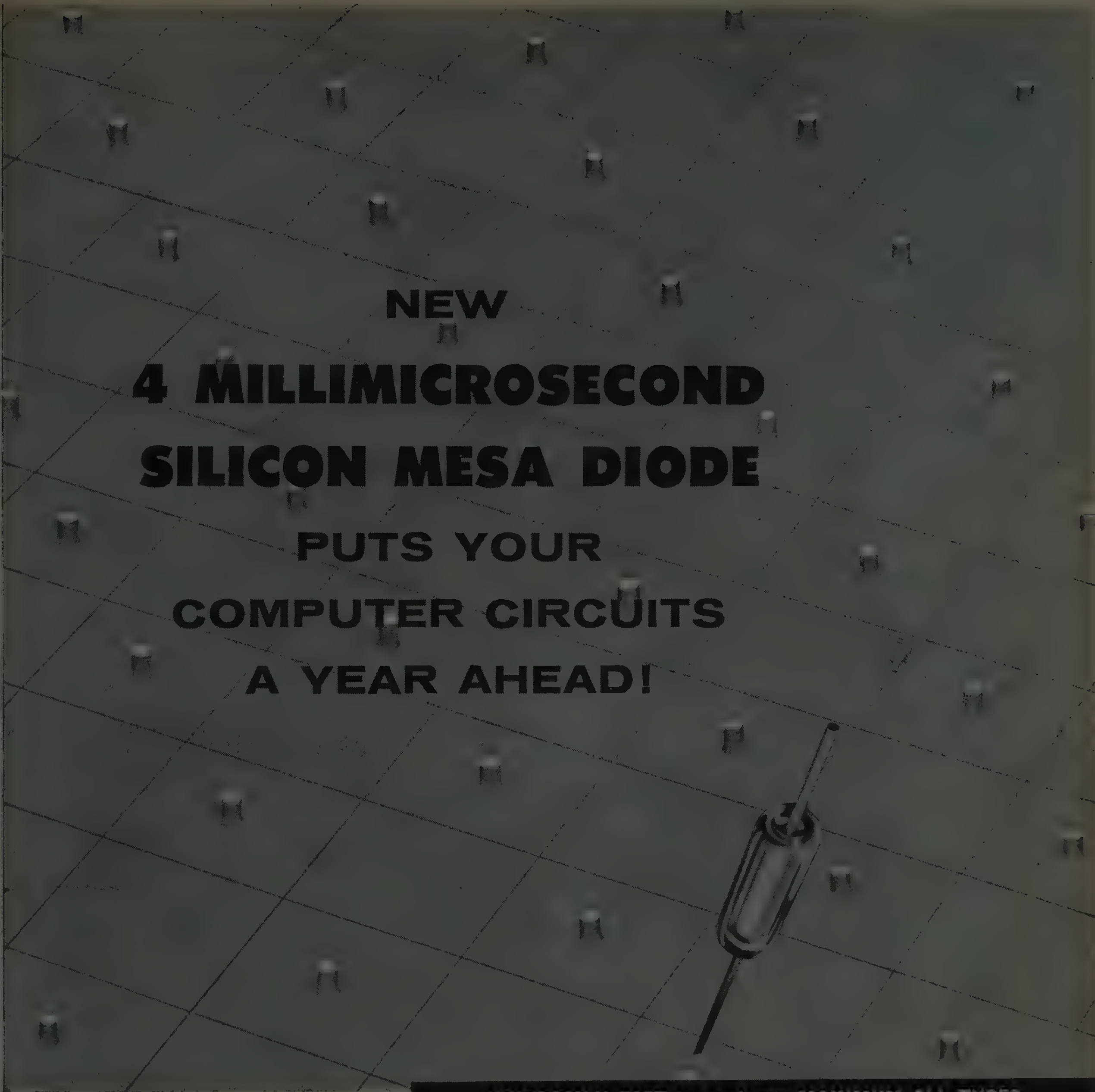
For further information and prices, write to **Uni-Seal, Inc.,** 477 North Ave., Garwood, N. J.

Circulators



Monogram Precision Industries, Inc., Cascade Research Div., 5245 San Fernando Rd., W., Los Angeles 39, Calif., has developed and made available a new line of Y, T and Cross-type circulators covering S-G-J-XL-X-K bands. This series is one-tenth to one-fifth the size and weight of corresponding conventional circulators and features an insertion loss of one-half and an isolation of twice that of other similar

(Continued on page 222A)



A newly developed silicon mesa diode gives millimicrosecond recovery time (*in normal, forward switching*) with high breakdown voltage. These characteristics can be the solution to many of last year's, this year's, — and next year's computer circuit problems.

The six diodes in the table below are in current production and available. Contact our sales department for immediate quotations.

UNIFORMLY FAST t_{rr} = 4 mμs MAXIMUM ALL TYPES

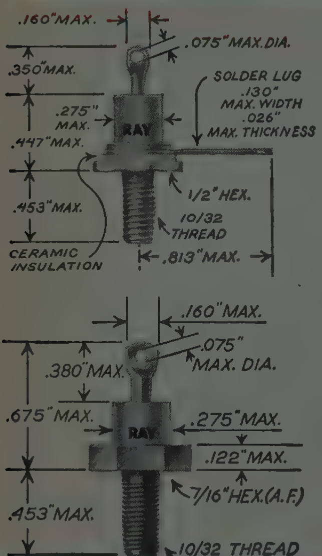
TYPE	Peak Reverse Voltage @25°C & 1.0μA	Peak Reverse Voltage @100°C & 10μA	Capacitance (@ —6 Volts)	Forward VoltageDrop @25°C and 10 mA
4226	20 Volts	20 Volts	1.0 μμf	1.1 Volts
4223	30 Volts	30 Volts	1.0 μμf	1.0 Volt
4222	40 Volts	40 Volts	1.0 μμf	1.0 Volt
4227	20 Volts	20 Volts	2.5 μμf	1.0 Volt
4228	30 Volts	30 Volts	2.5 μμf	1.0 Volt
4229	40 Volts	40 Volts	2.5 μμf	1.0 Volt

MICROWAVE ASSOCIATES, INC.
BURLINGTON, MASSACHUSETTS • BRowning 2-3000

NEW RAYTHEON SILICON TRANSISTORS

Diffused-Base "MESA" Construction
- NPN High Speed, High Gain Switches
- NPN High Frequency and Video Amplifiers
  - Close parameter control
  - Up to 50 megacycles minimum f_{ab}

High Voltage PNP Fusion Alloy Transistor
- $V_{CBO} = -100$ volts max.
- $V_{CEO} = -80$ volts max.
- $V_{EBO} = -60$ volts max.



New 4 Amp Silicon Rectifiers (Temperature Range −65°C to +165°C)

NON-INSULATED Cathode to Stud	NON-INSULATED Anode to Stud	INSULATED STUD	Peak Operating Voltage −65°C to +165°C volts	Ave. Rectified Current 25°C amps.	Ave. Rectified Current 150°C amps.	Reverse Current max. μA at Specified Voltage 25°C	Reverse Current 150°C	Reverse Current volts
1N2512	**1N2512R**	**1N2518**	100	4.0	1.0	2.0	250	100
1N2513	**1N2513R**	**1N2519**	200	4.0	1.0	2.0	250	200
1N2514	**1N2514R**	**1N2520**	300	4.0	1.0	2.0	300	300
1N2515	**1N2515R**	**1N2521**	400	4.0	1.0	2.0	300	400
1N2516	**1N2516R**	**1N2522**	500	4.0	1.0	2.0	350	500
1N2517	**1N2517R**	**1N2523**	600	4.0	1.0	2.0	400	600

NEW RAYTHEON GERMANIUM TRANSISTORS

- Complementary circuitry with Raytheon PNP types
- Highest reliability
- Excellent fast switching characteristics
- Low saturation voltage

High Speed Switches (Temperature Range −65°C to +175°C)

Type	V_{CB} max. volts	I_{CO} $V_{CB} = 6$ volts max. µA	V_{EB} max. volts	H_{FE} $I_C = 10$ ma $V_{CE} = 5$ volts min.	V_{SAT} $I_C = 5$ ma $I_b = 2.5$ ma max. volts	f_{ab} $I_E = 1$ ma $V_{CE} = 6$ volts ave. Mc	R_b' ave. ohms	C_{ob} ave. µµf
2N1386	25	.1	3	30	.6	60	60	3.5
2N1387	30	.1	3	20	.6	50	60	3.5

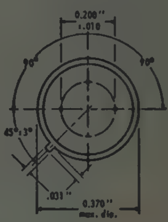
TO-5

High Frequency and Video Amplifiers (Temperature Range −65°C to +175°C)

Type	V_{CB} max. volts	I_{CO} $V_{CB} = 15$ volts max. µA	F_t $V_{CE} = 6V$ $I_E = 1$ ma Mc	R_{in}* at 10 Mc ave. ohms	R_{out}* at 10 Mc ave. ohms	Power Gain at 10 Mc ave. decibels	Gain-Bandwidth Product ave. Mc
2N1388	45	.5	60	500	5000	20	75
2N1389	50	.5	30	500	5000	15	45
2N1390	20	.8 @ 6V	12	400	6000	12	—

*Measured resistive component of the impedance

E3-44



High Voltage PNP (Temperature Range −65°C to +160°C)

Type	V_{CB} max. volts	V_{CE} max. volts	I_{CO} max. µA	H_{FE} $I_B = 0.1$ mA $V_{CE} = -0.5$ V ave.	R_{SAT} max. ohms	V_{EB} max. volts
2N1275	−100	−80	1.0	15	60	−60

NEW RAYTHEON 4 AMP SILICON RECTIFIERS

3 Constructions for design and operating convenience

STUD INSULATED
STUD CONNECTED TO CATHODE
STUD CONNECTED TO ANODE

Low reverse current
High forward conductance
Fast reverse recovery
Exceptional stability

NPN Switches — Medium Current High Frequency, High Gain (Temperature Range −65°C to +85°C)

Type	V_{CB} max. volts	f_{ab} min. Mc	H_{FE} ave. $I_C = 50$ mA $V_{CE} = 1.0$ V	R_{SAT} ave. ohms
2N438	25	2.5	25	2
2N439	20	5.0	45	2
2N440	15	10.0	70	2

TO-5

NPN High Gain IF and Converter For Broadcast and Auto Radio (Temperature Range −65°C to +85°C)

Type	Circuit Usage	V_{CE} max. volts	I_{CO} max. µA	C_{ob} f = 1 Mc ave. µµf	Gain 455 Kc db
2N1366	Converter	12	20	11	28*
2N1367	IF	12	20	11 ± 3	38

*Conversion Gain

E3-44

RAYTHEON®

SEMICONDUCTOR DIVISION

RAYTHEON COMPANY

SILICON AND GERMANIUM DIODES AND TRANSISTORS • SILICON RECTIFIERS • CIRCUIT-PAKS

New York, PLaza 9-3900 • **Boston,** HIllcrest 4-6700 • **Chicago,** NAtional 5-4000 • **Los Angeles,** NOrmandy 5-4221 • **Orlando,** GArden 3-1553
Syracuse, GRanite 2-7751 • **Baltimore,** SOuthfield 1-0450 • **Cleveland,** WInton 1-7716 • **Kansas City,** PLaza 3-5330 • **San Francisco,** Fireside 1-7711
Canada: Waterloo, Ont., SHerwood 5-6831 • **Government Relations:** Washington, D. C., MEtropolitan 8-5205

NEWS New Products IRE

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 218A)

circulators. The simple mechanical design affords rugged construction, permitting environmental reliability not heretofore possible in conventional models. The new circulators lend themselves ideally to Master, Parametric Amplifier and duplexer applications.

General specifications are: peak power, 100 kw; average power, 100 watts; maximum insertion loss, 0.5 db; minimum isolation, 20 db; Maximum vswr, 1.2; Frequency Band, 5% or more.

Disc Capacitors

Three new high capacitance ceramic disc capacitors have been added to the line of "DD" Series Hi-Kaps, it was announced by **Centralab, Div. Globe Union, Inc.**, 900 E. Keefe Ave., Milwaukee, Wis. With capacitances of 0.03, 0.04 and 0.05 μf, 600 volts dc, these units measure $\frac{7}{8}$ inch in diameter and 15/64 inch thick. They are "Durez" coated and impregnated with high melting point wax to withstand extremes of temperature and humidity.

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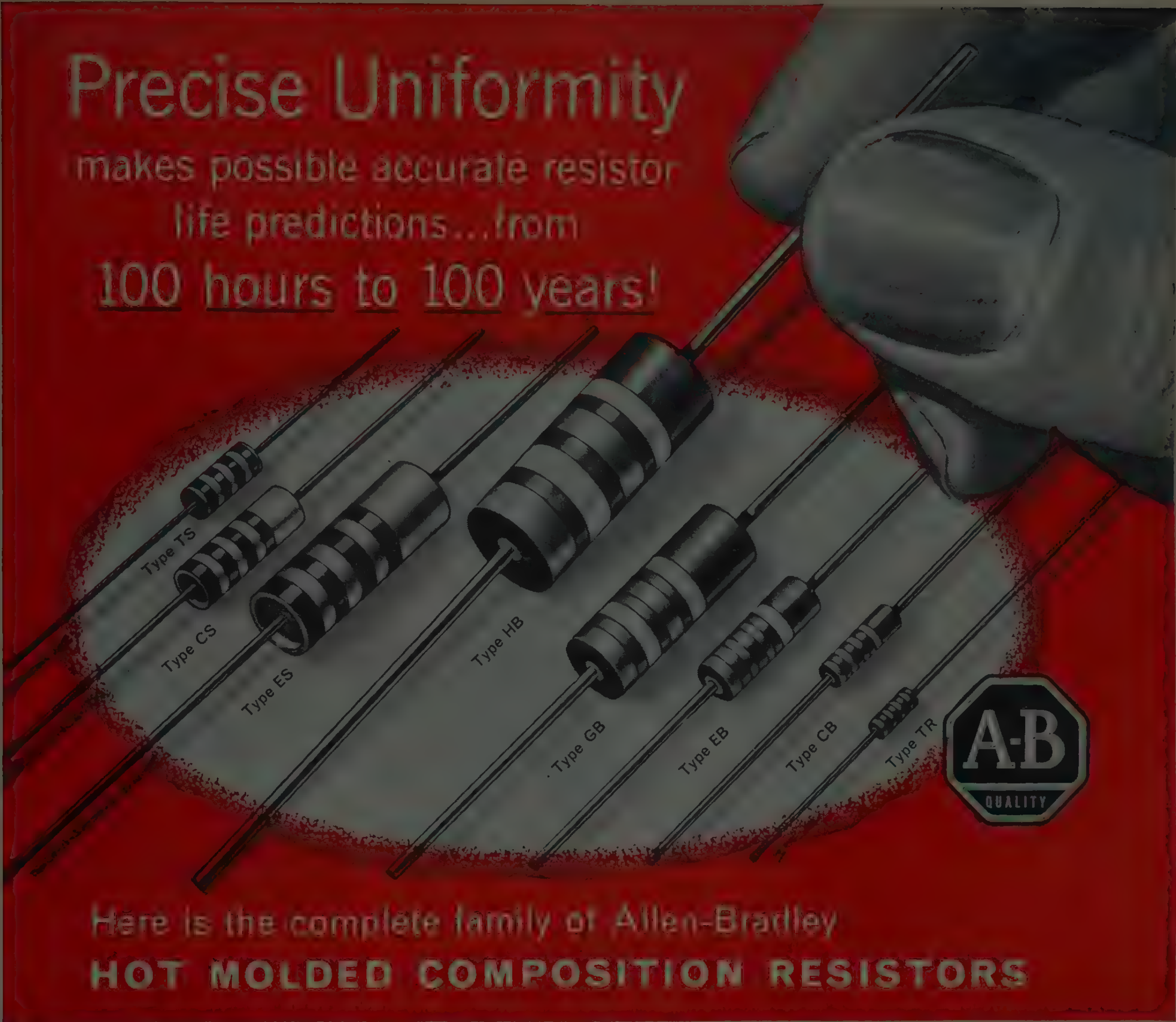
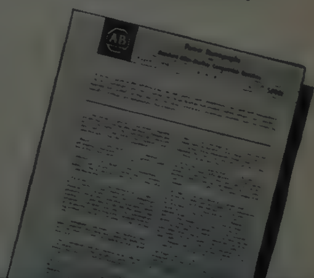


The exclusive hot molding process—developed and perfected by Allen-Bradley—produces resistors so uniform in their characteristics that, when combined with the analysis of test data accumulated over the years, it becomes possible to *accurately* predict the "life" of an Allen-Bradley resistor—from 100 hours to 100 years.

After years of carefully compiling test information obtained by Allen-Bradley Environmental Laboratories, as well as from many independent laboratories, power nomographs have been developed which show the relationship between power input, temperature rise, ambient temperature, life, and permanent resistance change for the standard Allen-Bradley composition resistors.

Inasmuch as catastrophic failure is unknown to occur with Allen-Bradley resistors, the design engineer can safely develop circuitry where predictable changes of characteristics are known and uniform. Furthermore, with Allen-Bradley resistors, changes due to humidity are temporary and cause no permanent damage to the resistors. Voltage characteristics and temperature characteristics are uniform and are known factors. No other composition resistors possess such uniformity of mechanical configuration, electrical characteristics, and life performance as do these A-B quality resistors.

The power nomographs published in the Allen-Bradley Technical Bulletin 5000E will eliminate all uncertainty of circuitry design in relationship to resistors—provided Allen-Bradley "quality" resistors are used. You will find this information very useful. Bulletin 5000E will be sent to you upon your request.



ALLEN-BRADLEY *Quality* ELECTRONIC COMPONENTS

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee 4, Wis. • In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

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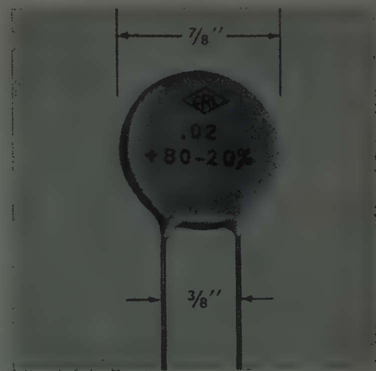
No. 22 tinned copper leads are $1\frac{1}{2}$ inches long.



Primarily designed for by-pass, coupling and filter applications, these "DD" series units are available from stock through electronic parts distributors. A separate group, the "ID" series, rated at 500 volts dc are available from parts distributors in industrial quantities only.

Power Supply

Designed as a component for use with computing systems or strain gauge apparatus, the PI(plug-in) series of power supplies developed by **Mid-eastern Electronics, Inc.**, 32 Commerce St., Springfield, N. J., have a capacity of 15 watts output with 0.1% regulation. The output may be fixed, or variable over the entire range by means of a screwdriver adjustment. Voltage ranges are available from 0 to 300 volts dc; such as, 100 volts at 50 ma, or 50 volts at 100 ma.

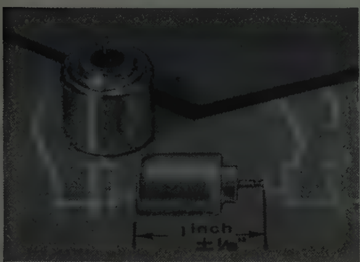
A transistor regulator circuit provides fast response and accurate regulation for both line and load changes. Recovery is less than 50 μs; Ripple, 0.01% and Overshoot is less than 1.0% of the voltage setting. Extra pins on the octal plug may be used to insert a fuse in the external load circuit for overload protection. The sup-

ply is programmable over a narrow voltage range. Dimensions: $4\frac{1}{8} \times 4\frac{7}{8} \times 6\frac{1}{2}$ inches. Weight: 3 pounds.

Large RF Connectors

To accommodate some of the older miniature rf cables, such as RG-68 C/U and RG-59 A/U, which are considerably larger in diameter than the latest Service specification subminiature cables, **Sealectro Corp.**, 139 Hoyt St., Mamaroneck, N. Y., is offering the "ConheX" Types 3040 and 3050 cable plugs. While these connectors have a larger body and clamping components than the regular "ConheX" 75-ohm series, they will mate with the 75-ohm "ConheX" receptacles and jacks. The accompanying photo shows the larger Type 3040 alongside the 75-ohm size.

Liquid Electrolyte Tantalum Capacitors



Ruggedized high capacitance military types CL-15, CL-39, CL-40 and CL-43 tantalum capacitors are announced by **The Magnavox Co.**, Dept. 822, Fort Wayne, Ind. Ratings up to 150 μf at 30 volts and 50 μf at 90 volts. Designed to meet applicable military requirements in Mil-C-3965B and other similar specifications. Operating temperature range $-55°C$. to $125°C$. Units are hermetically sealed and will meet salt spray, shock, vibration, moisture resistance, reduced pressure and other similar tests. Case is $\frac{3}{8}''$ in diameter and is at ground potential. Electrical leakage is low and capacitance variation with temperature is at a minimum. Further information can be supplied by the firm.

Silicon Rectifiers Heat Sink

A new insulated base stud which dissipates heat more efficiently has been announced by **Advanced Vacuum Products, Inc.**, Stamford, Conn. The company is a

(Continued on page 226A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 225A)

wholly-owned subsidiary of General Ceramics Corp., Keasbey, N. J. The improved design was developed in collaboration with Bradley Semiconductor Corp., New Haven Conn.

Bradley produces the rectifier element and combines the rectifier and the insulated base in a one-piece, compact unit, which is marketed in various sizes under the "Redtop" trademark.

The new design is said to improve rectifier performance and, at the same time, sharply reduce heat sink installation costs by eliminating the assembly of mica washers and other conventional hardware.

The new unit consists of an oxygen-free copper tab brazed to an alumina ceramic insulating disc which is, in turn, brazed to an oxygen-free copper stud. The combination of high thermal conductivity and electrical insulation in the alumina provides heat transfer properties superior to ordinary washer assemblies. This permits the efficient use of smaller heat sinks.

Maximum temperature cycling requirements for silicon rectifiers run from −60° to +200°C. The new diode bases substantially exceed that temperature range. The units are capable of handling up to 2,000 volts.

Noise Generator

GPS Instrument Co., Inc., 180 Needham St., Newton, Mass., has developed a noise generator intended for use in the simulation and study of problems involving random processes. Model NG1000A, provides source of random noise with an amplitude distribution that is gaussian, and a frequency spectrum that is variable over a wide range, compatible with the computer time-scale. For other than gaussian distribution, a standard GPS Function Generator may be used to shape the output of the Noise Generator to achieve the desired amplitude distribution.

(Continued on page 228A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

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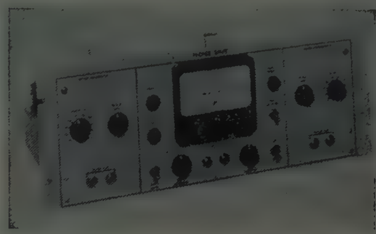


Model NG1000A and associated Probability Distribution Analyzer are companion equipment to the GPS Compressed-Time-Scale Analog Computer, which combined form the GPS High-Speed Statistical Analog Computer.

The noise generator contains an electronic metering circuit for direct reading of the rms and mean value of either the generated noise or the noise on any variable in the system being simulated.

The noise generator amplitude distribution is gaussian to within ± 2 per cent probability from 2 percent to 98 percent probability. Its rms output voltage is variable from zero to a maximum value depending upon the shaping filter use: 6 volts rms for the widest bandwidth filter down to 1 volt on the narrowest filter.

Meter reads mean and standard deviation of noise signals with gaussian amplitude distribution. For reading rms value of noise of any arbitrary distribution, a Multiplier may be used (as a squaring device) with its output connected to the noise generator metering circuit. The noise generator fits the standard 19-inch rack.

Pressure Transducers

Two new pressure transducers which measure full system differential pressures at each port are now being manufactured by **Standard Controls, Inc.** 1130 Poplar Place, Seattle 44, Wash.

Both models, SP2-399 and SP2-517, feature small size and rugged construction for missile and rocket hydraulic system applications where space and weight is especially critical.

Used in hydraulic radar antenna positioning systems, these transducers will

(Continued on page 230A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 228A)

change the action of a flow-control servo valve to pressure-control in certain operational modes.

The SP2-399 is furnished with a 4-conductor pigtail, the SP2 elements connected in a full bridge with all active legs.

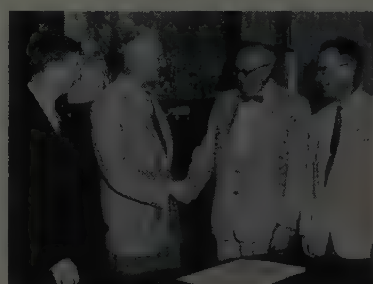
Pressure ratings are from 0–100 through 0–5000 psid. Sensitivity can be from 2 mv per volt to 4 mv per volt. The temperature range is −28° to +275° F per degree F.

Errors from non-linearity and hysteresis combined are less than 1.0% of full scale. Nominal bridge impedances are 350 to 900 ohms. Other impedance values can be provided.

For complete details, write to the company for Bulletin SP-2.

Atlantic Research Acquires Jansky & Bailey

Atlantic Research Corporation of Alexandria, Va., has completed negotiations that will make **Jansky & Bailey, Inc.**, of Washington, D. C., a wholly-owned subsidiary. The transaction also gives ARC a substantial stock interest in General Communication Company of Boston, Mass., which formerly owned Jansky & Bailey. The arrangement, which became effective October 1, was announced jointly today by Dr. Arch Scurlock, President of Atlantic Research Corp.; Harold A. Potsdam, President of General Communication Co.; and C. M. Jansky, Jr., Chairman of the Board, and Stuart L. Bailey, President of Jansky & Bailey, Inc.



L to R Scurlock, Sloan, Jansky and Bailey

Jansky & Bailey, Inc., which has operated since 1930, will continue under its present policies and technical management, with Messrs. Jansky and Bailey retaining their present positions. Key personnel in Jansky & Bailey are acquiring stock interest in Atlantic Research.

Sixteen per cent of the outstanding General Communication stock will also be acquired by Atlantic Research in the transaction. Additional options extending over 5 years make it possible for Atlantic Research ultimately to acquire over 25 per cent of General Communication stock.

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why design your own

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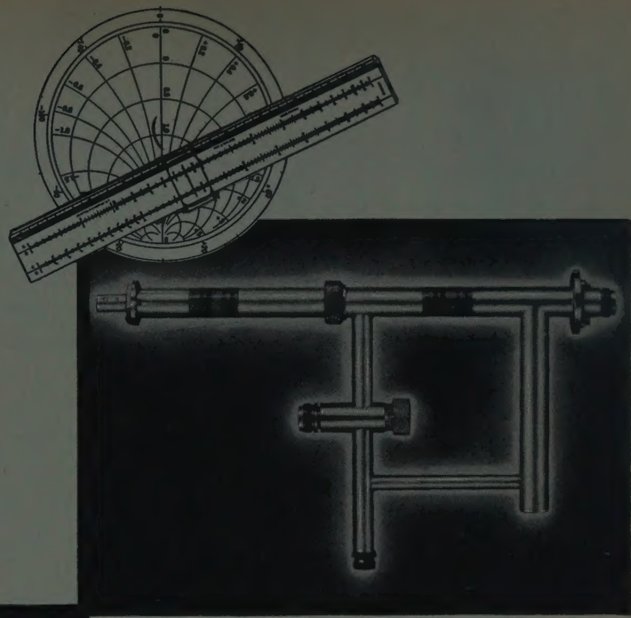

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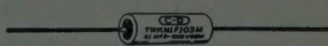
in accordance with Spec.
MIL-C-14157A
300, 400, 600 volts DC Working

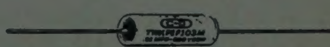
Uninsulated Body Type CPM08

Insulated Body Type CPM09

MILITARY & INDUSTRIAL
"TWK" SERIES
in accordance with
MIL-C-26244 (USAF)
200, 300, 400, 600 volts DC Working



Uninsulated Body Type TWKN
(equivalent to MIL-CPV08)



Insulated Body Type TWKP
(equivalent to MIL-CPV09)

CAPACITANCE:
001 mfd. to 1.0 mfd.

TEMPERATURE RANGE:
—55°C to +125°C.

Cornell-Dubilier Certified High-Reliability Capacitors meet performance expectations for new environments and new complex military and industrial electronic equipment. These capacitors meet or surpass the exacting requirements of MIL-C-14157A and MIL-C-26244(USAF). Each production lot is furnished with certified test data covering the stringent test program detailed in the specification.

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